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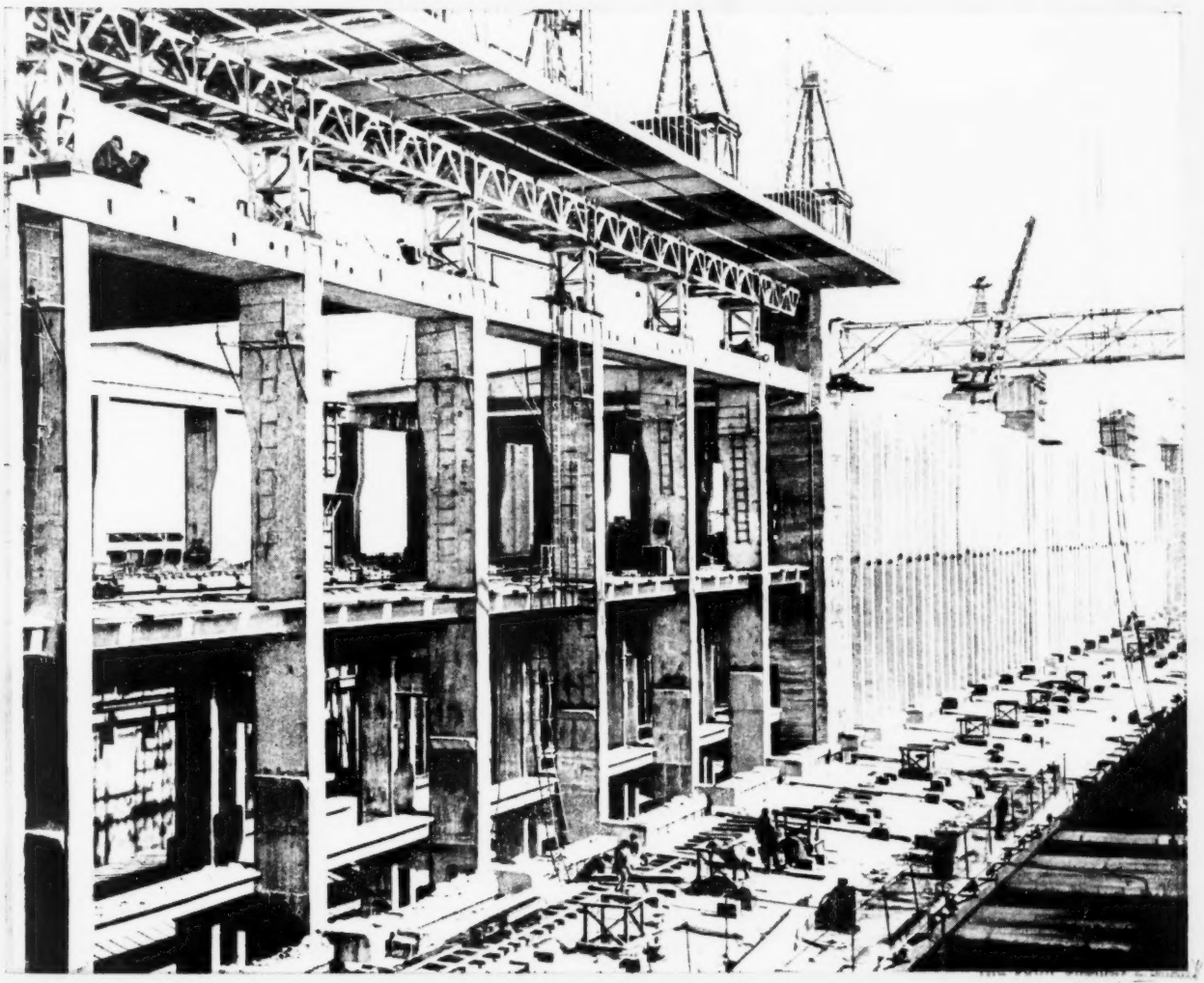
163

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

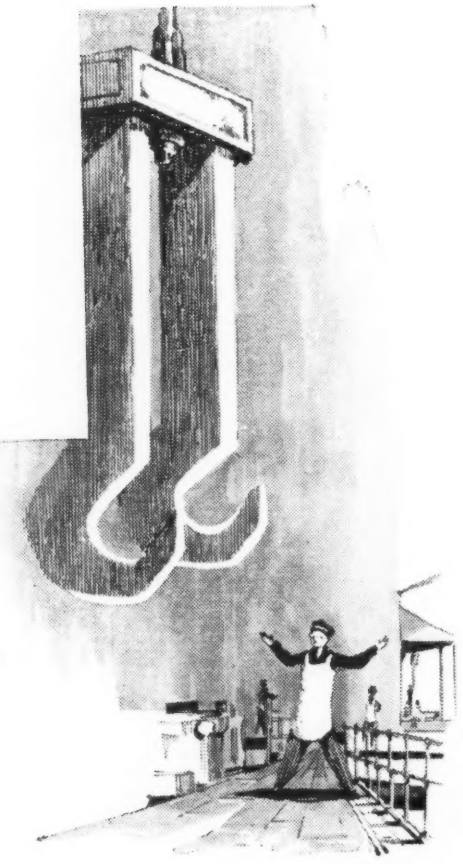
VOL. X NO. 6 JUNE, 1960 RUPEES TWO



STALINGRAD HYDROPOWER STATION UNDER CONSTRUCTION

OCT 20 1960

Ajanta G 100

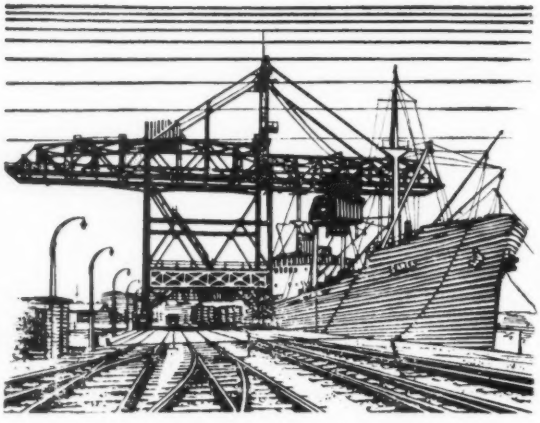


CAN SAY

move
remove
go
hie
lift
shift
hoist
carry
winch
convey
transport
elevate
lower
push
pull
roll
crush
feed
transfer
go up
go down
go round
circumnavigate

, but the correct word
for MAXIMUM
EFFICIENCY is

MOXEY



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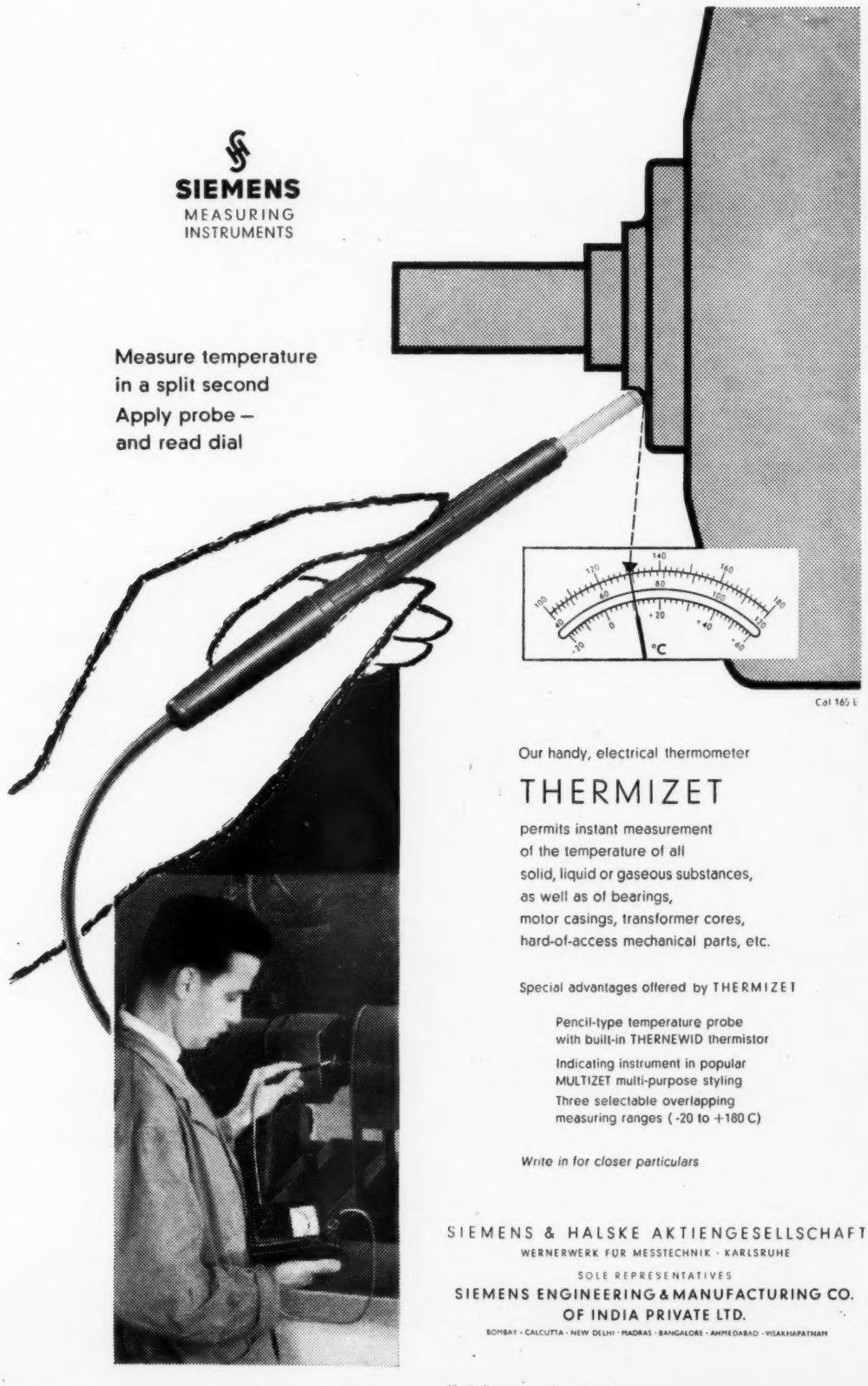

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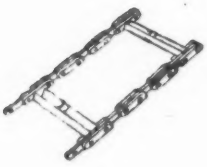
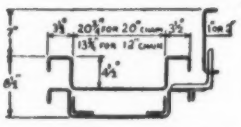
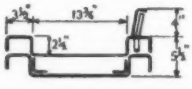


GENERAL DETAILS



STANDARD TYPE WITH OFFSET SPILLPLATE

METHOD OF APPLYING "ZEDD" LIDS



LOW TYPE WITH "DROP-IN" SPILLPLATE

The Cowlishaw, Walker Conveyor has a top pan detachable from the bottom pan, providing unique easy access to return chain.

At the ends of top and bottom pans embracing butt scraps provide easy snaking on simple articulated metal joints, thus ensuring no leakage of coal.

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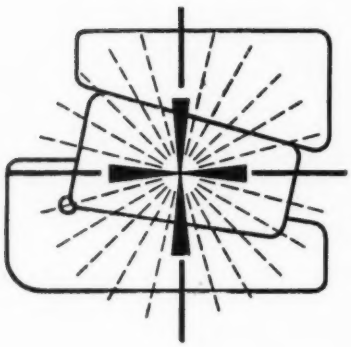
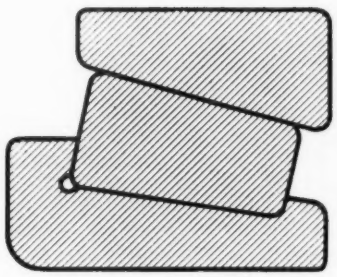
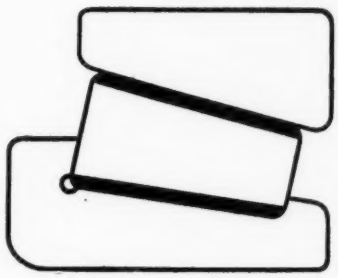
A Timken bearing rolls the load in machinery, *virtually eliminates friction* wherever wheels and shafts turn. It helps increase the life of machines while reducing maintenance. Here's how:







a The Timken bearing takes any combination of radial and thrust loads because of its *tapered* design. With Timken bearings you don't need extra thrust devices.

b The Timken bearing is made from the finest bearing-quality alloy steel available. This enables it to shrug off shock loads in rugged industrial service.

c The Timken bearing gives extra load-carrying capacity because there's full-line contact between rollers and races. Result: maximum capacity in minimum space.

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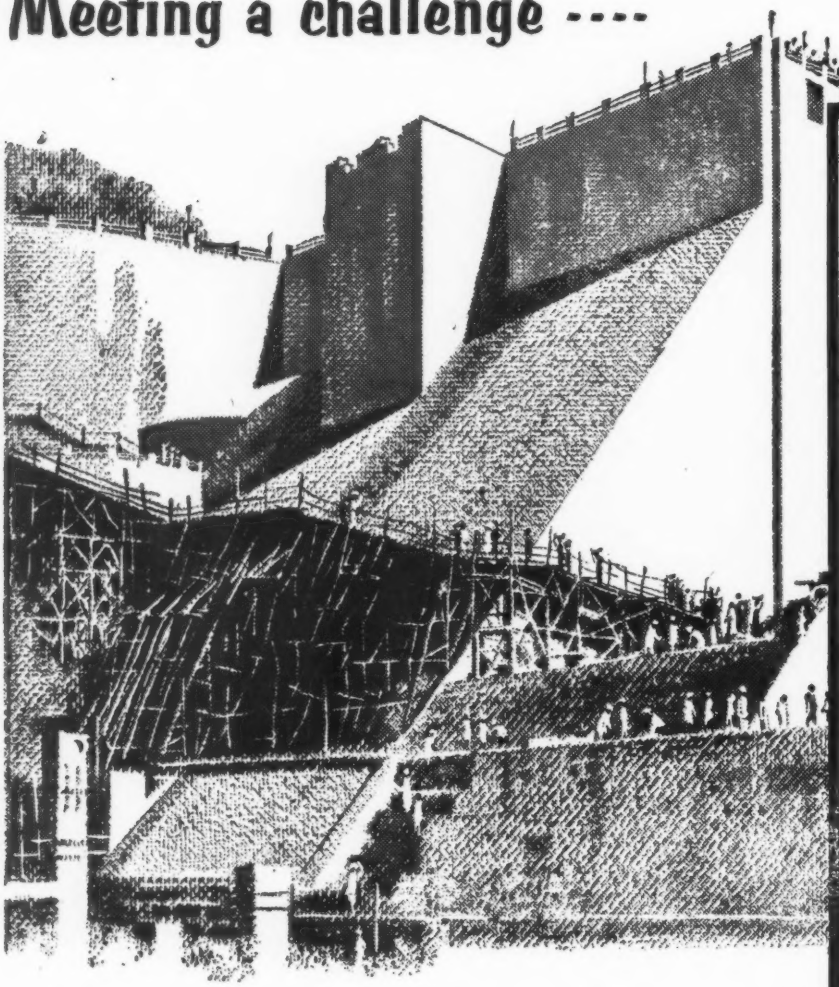
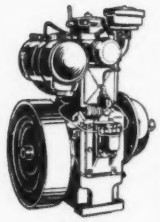
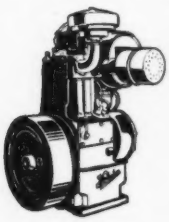




5 H. P.



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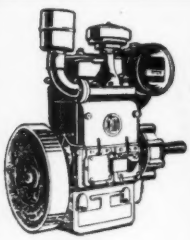

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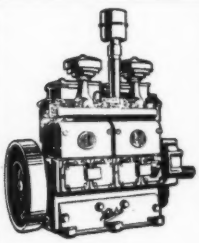

40 H. P.

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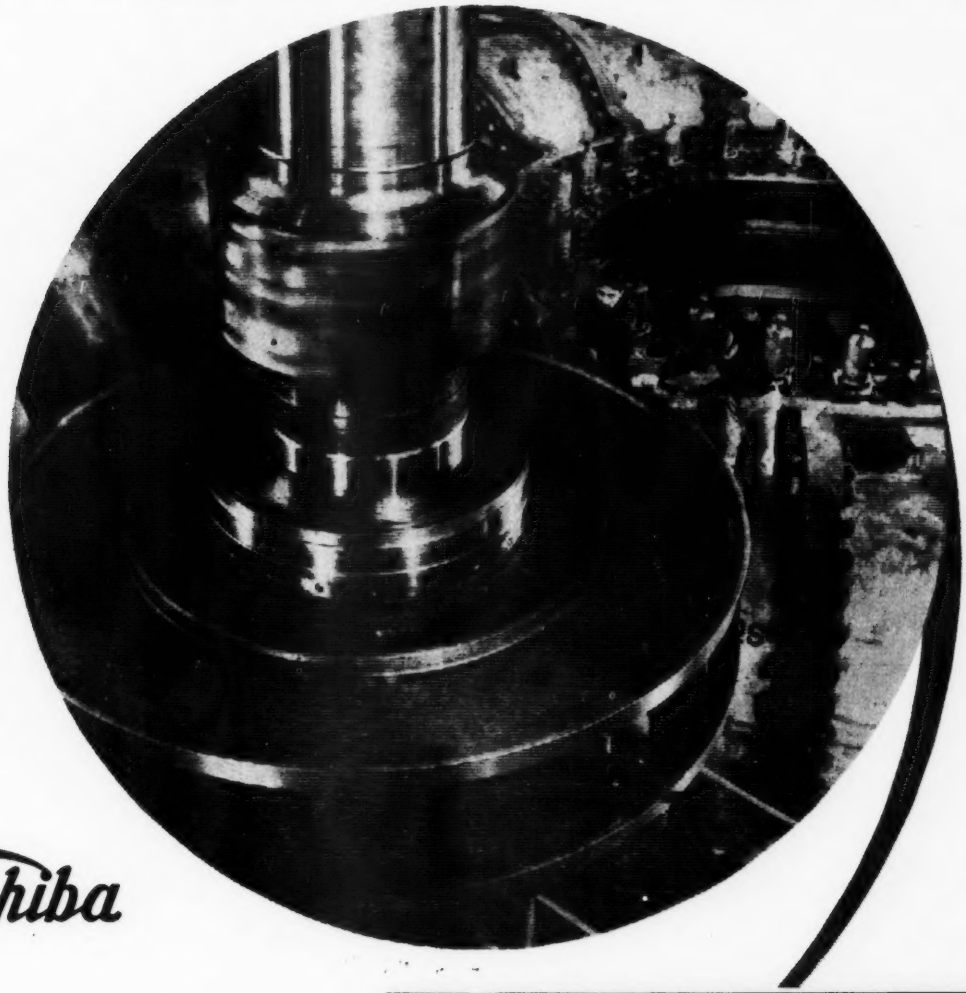

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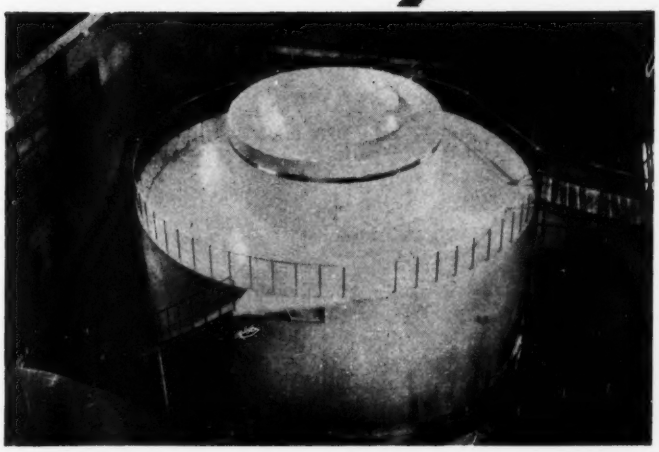

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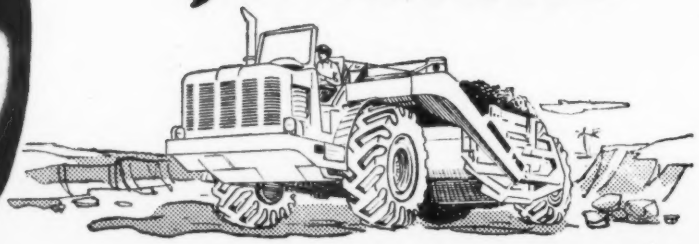

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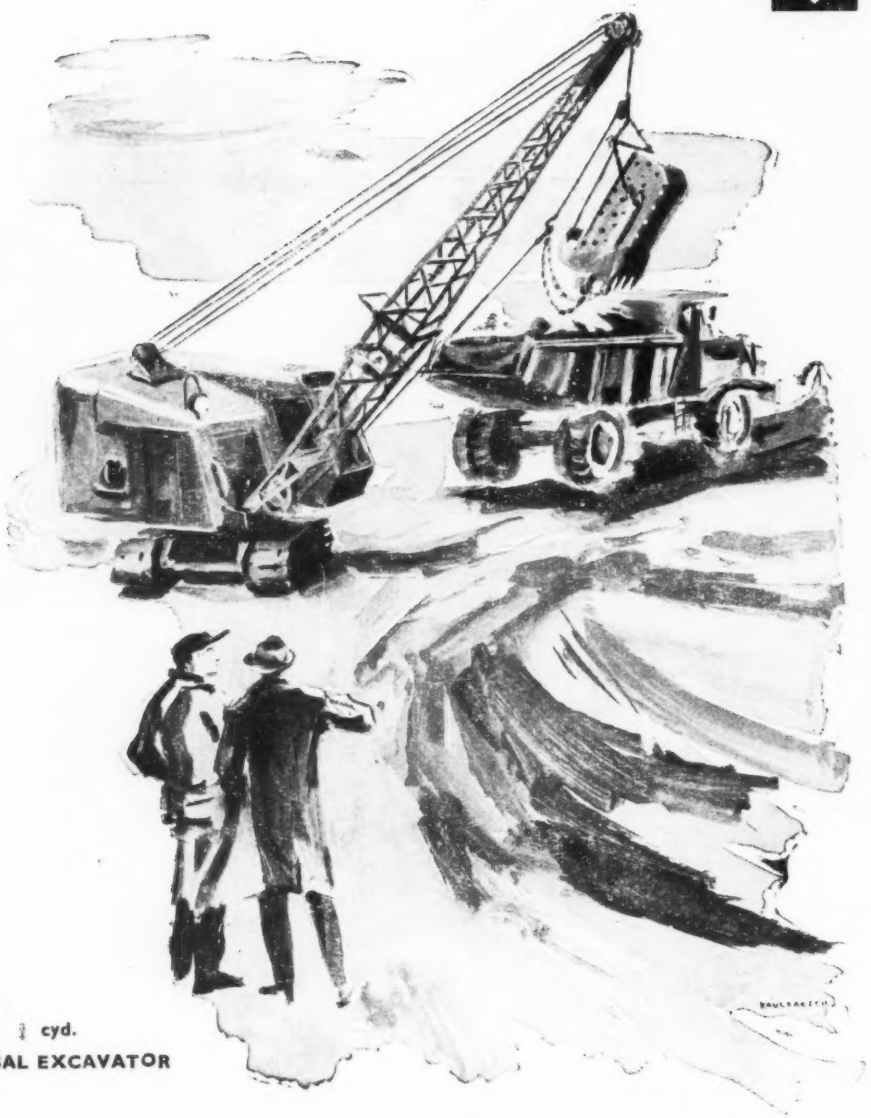

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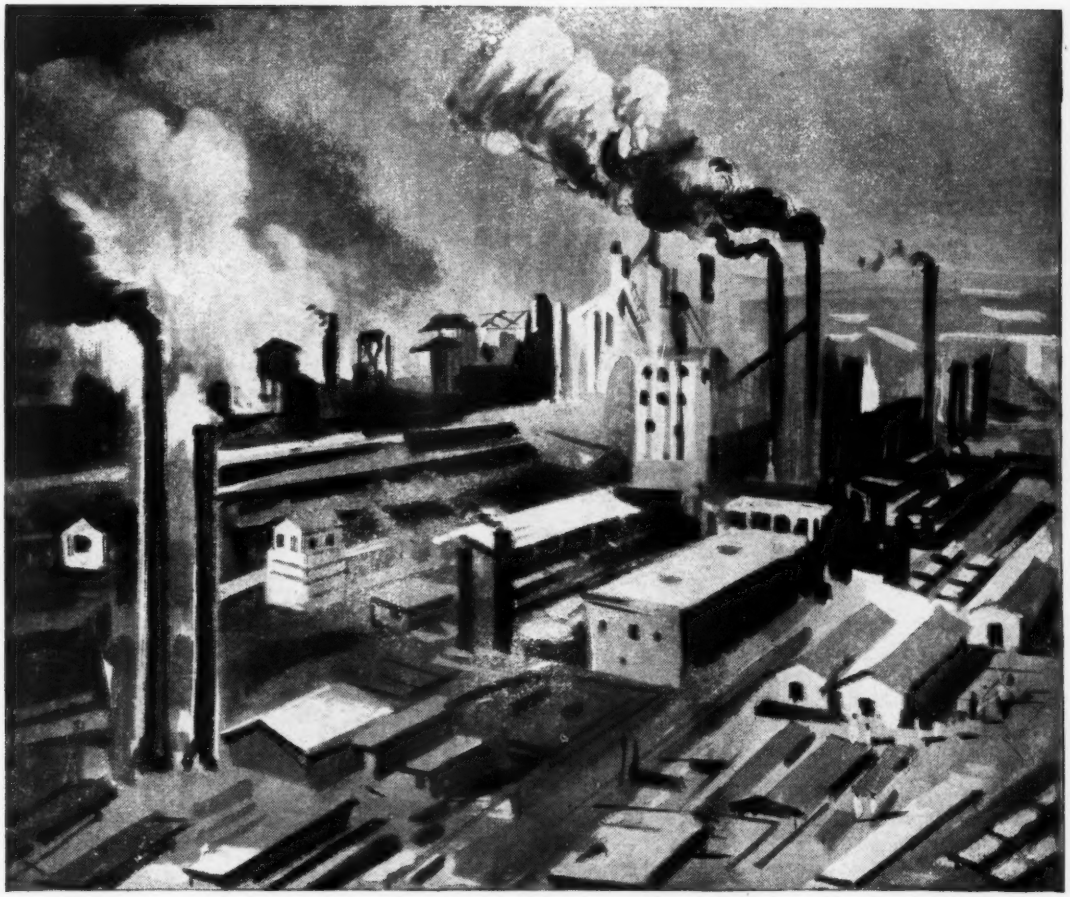

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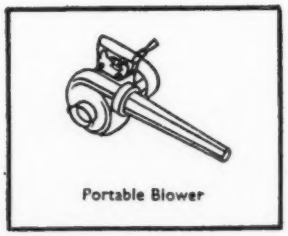

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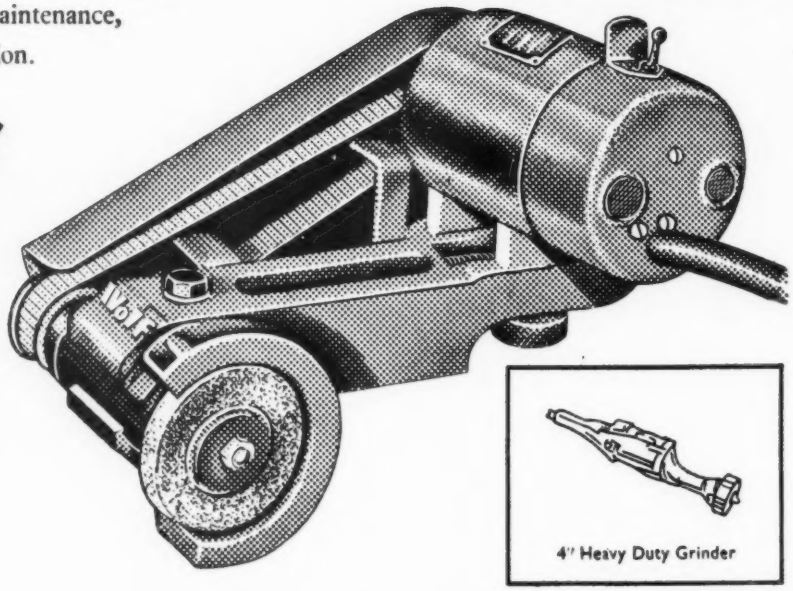

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4" Heavy Duty Grinder

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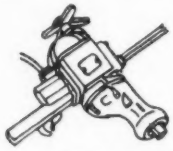
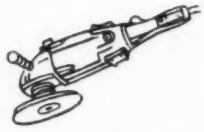
1/4" & 3/8" Heavy Duty Drills



1" & 1¼" Heavy Duty Drills

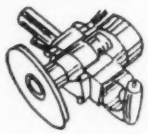


7" Heavy Duty Sander

1/4" Production Drill

½" General Duty Drill

½", 5/8", ¾" Heavy Duty Drills



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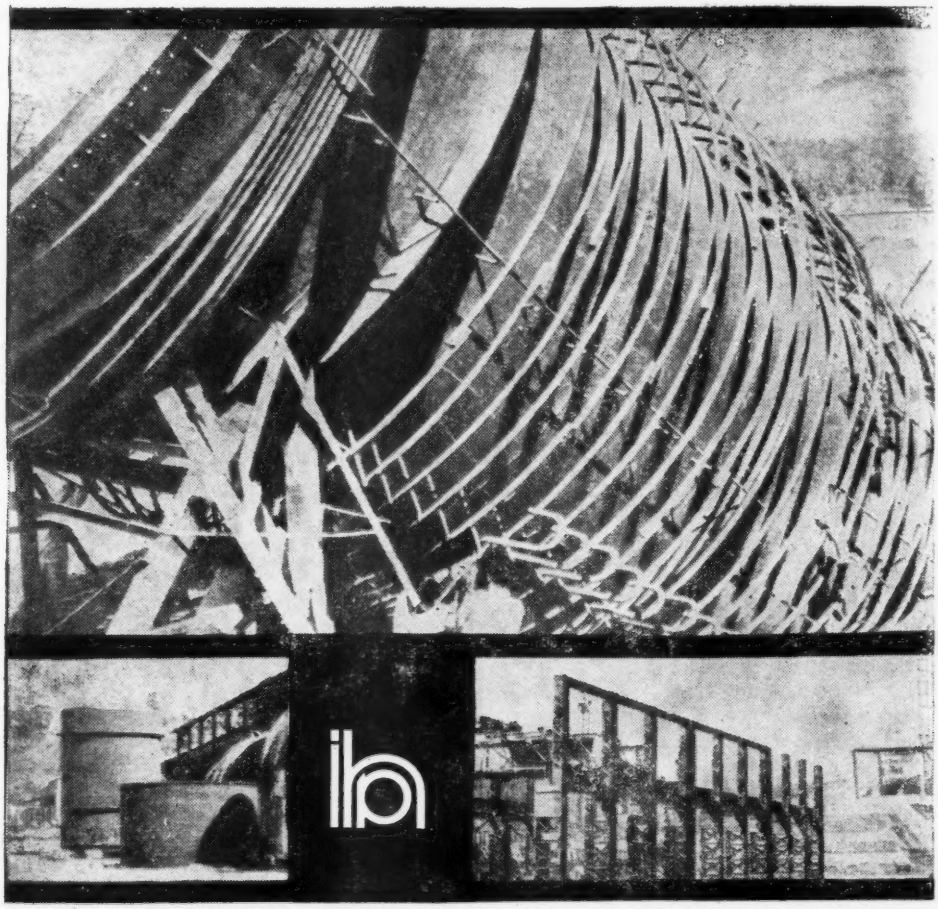

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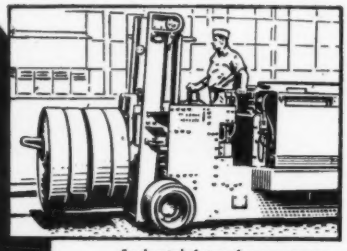

Industrial trucks are more economical, handle more goods per shift. But battery-powered industrial trucks offer a further economy: their operating costs are far lower than those of similar petrol or diesel trucks

Battery-powered industrial trucks perform better than petrol or diesel types because torsion force is maximum when the truck is just starting. Draw-bar pull, too, is greater when the high-capacity STANDARD TPg Battery is used

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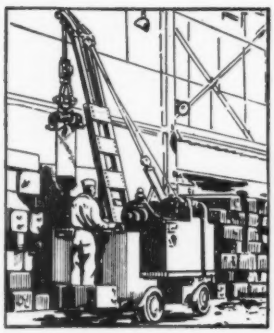
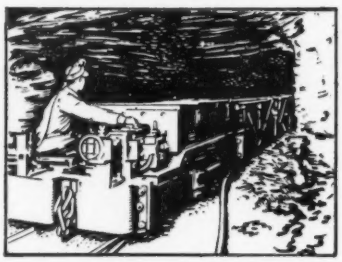
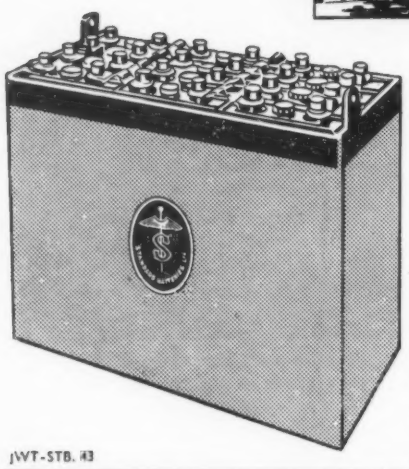




Battery-powered industrial trucks—of various types for warehouses, factories, mines, etc.—carry goods safely, help avoid costly damage. They bring down day-to-day handling costs, help reduce risks involving workmen's compensation



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Compared to ordinary batteries for industrial trucks, STANDARD TPg Traction Batteries offer a higher capacity-to-weight ratio, an increased service life up to 100% longer, and a saving of up to 10% in battery costs. Change to modern mechanical handling methods: and fit your industrial trucks with STANDARD TPg Batteries. Write today for more information !

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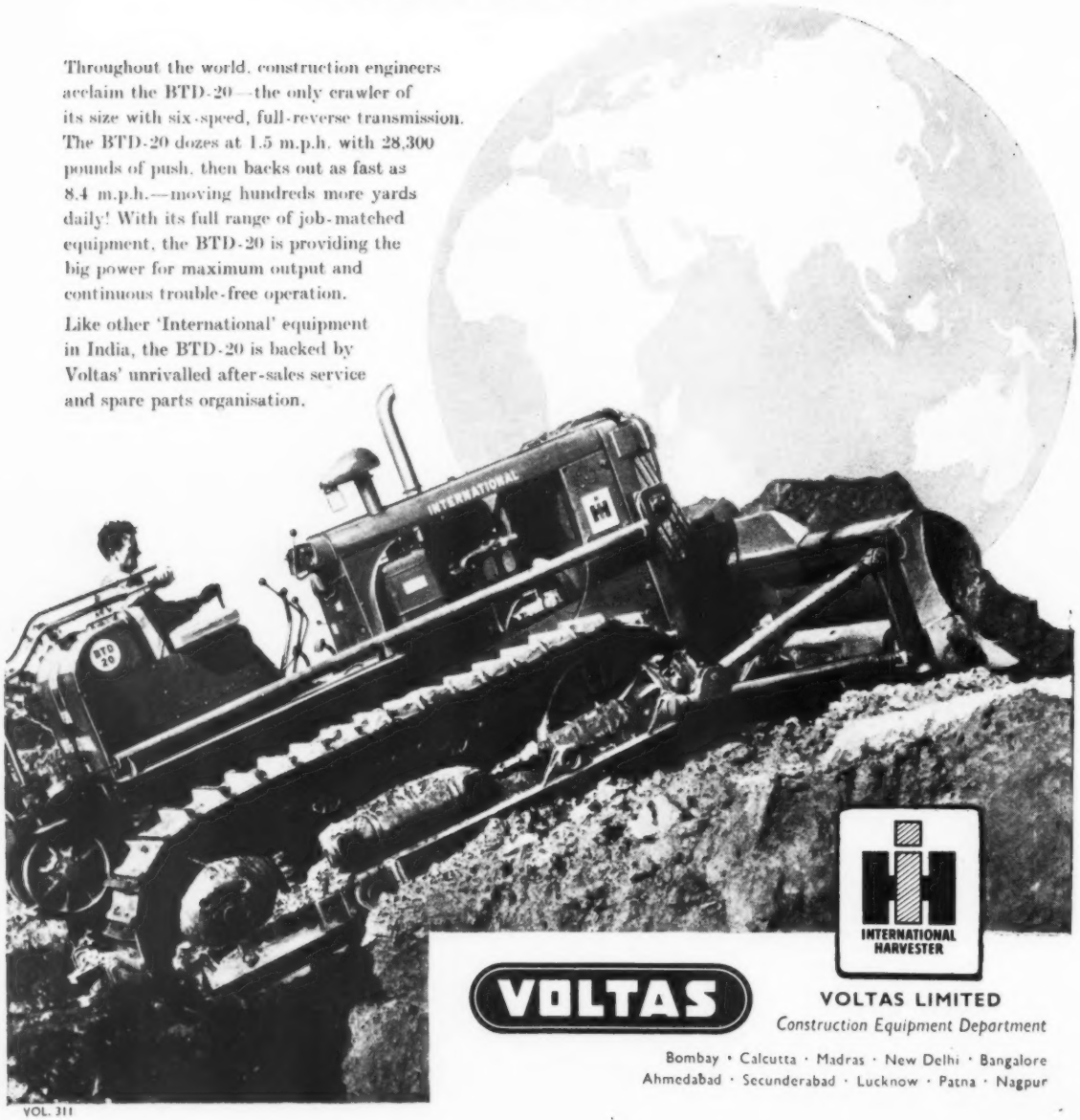

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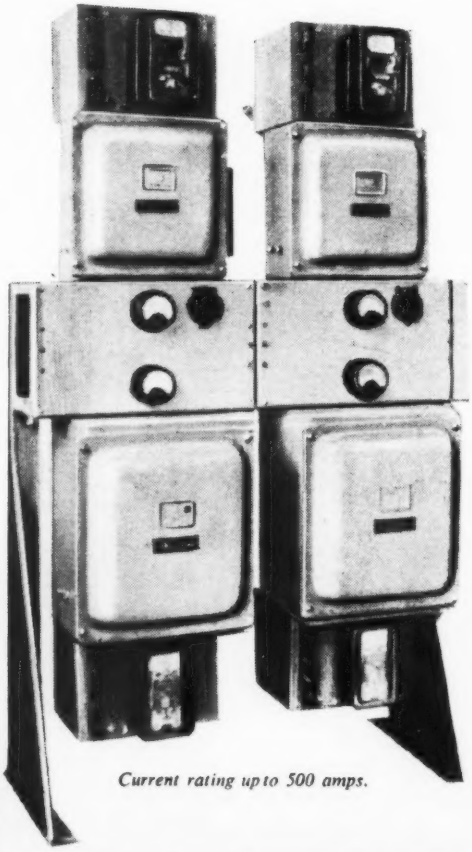

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Harnessing a New Zealand River for Electricity

By J. W. RIDLEY

Ultimately the hydro-electric project at Benmore will be the largest unit of a chain of stations designed for the maximum practicable use of the resources of the Waitaki River basin. Projected total capacity could exceed 1,500,000 kW.

The site is just below the confluence of the Ahuriri and Waitaki Rivers, about the centre of the South Island of New Zealand and in the northern part of the Province of Otago. It is some 88 miles and 60 miles respectively from the South Pacific ports of Timaru and Oamaru, in a picturesque region of high, bare hills, in sight of the snow-covered peaks of the Southern Alps (including Mount Cook,

Fig. 1: An artist's impression of the Benmore dam as it will appear when completed, drawn on an aerial oblique photograph of the site to give an indication of the extent of the new lake. The Waitaki River runs down the centre background, joined at left by the Ahuriri. Principal features are (1) Mount Cook; (2) Ahuriri River channel; (3) spillway control structure; (4) spillway channel, ending in a deflector which will throw the jet of water into the air, spreading it over a wide arc before it falls into the shovel-like rock channel leading to the river; (5) new access road, running along the crest of the dam and possibly down the left bank; (6) level area at the foot of the downstream slope; (7) penstocks and powerhouse; (8) concrete power intake structure; (9) outdoor transforming and switching stations; (10) tailrace. Water from the lake created by the next scheme in the development of the Waitaki basin, the Waitangi, may eventually back up well into the area shown at bottom left.

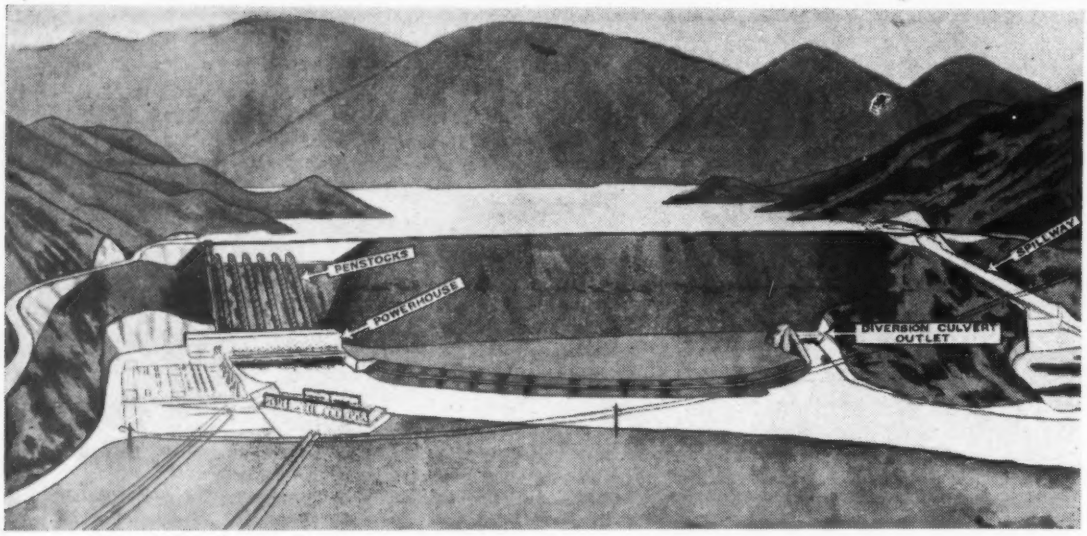

Fig. 2: A Preliminary perspective of the Benmore scheme showing the layout of permanent structures. The diversion culverts, later to be permanently sealed with concrete plugs, are shown at right, at the base of the dam.

12,349 ft.). One of the nearer important heights is Mt. Benmore (5,987 ft.).

Access is by main highway up the Waitaki Valley, and the dam site is 20 miles from the nearest railhead, at the village of Kurow.

The installed capacity of the proposed scheme is 540,000 kW and it is the largest single project in New Zealand both in capacity and annual output of units. It is in fact greater in capacity than the combined installations of the two previous largest stations in New Zealand, Roxburgh of 320,000 kW and Maraetai of 180,000 kW.

The Waitaki River at the Benmore site has the following flow characteristics :—Mean natural flaw, 12,000 cusecs ; Estimated 1 in 1,000 year flood flow, 120,000 cusecs ; estimated construction flood flow, 70,000 cusecs ; mean head available, 305 feet.

The project is sited at the lower end of the Upper Waitaki Gorge and is bounded by ridges of greywacke interspersed with some argillite layers. There are no major faults, and the bedding planes are steeply dipping and at right angles to the river flow, making it an ideal site for construction in this respect.

The base of the valley is wider than we have normally been accustomed to on hydro-electric sites in New Zealand and the depth of overburden in the form of sands and gravels is considerable. However, for construction of an earth dam these are not particularly difficult problems to overcome and the more open nature of the site has many advantages in hastening construction.

The estimated cost of the project is £36,400,000 (N.Z.) and first power by 1965 is the present objective.

PERMANENT STRUCTURES

The general disposition of the structure is as shown in the illustrations. Topographical features are such that the intake, penstocks and powerhouse are sited on a ridge on the right bank of the river looking downstream. The spillway discharges over another ridge on the left bank. The earth dam spans the valley in between.

Dominant feature of the project is the earth dam which will have a crest length of 2,000 ft., a maximum structural height of 360 ft. (hydraulic height of 305 ft.) and will contain 16,000,000 cubic yards of earth and rock fill. Approximate quantities are : Core of clayey gravels, 4,500,000 cub. yds. ; upstream shoulder of sands and gravels, 5,000,000 cub. yds. ; downstream shoulder of sands and gravels, 5,000,000 cub. yds. ; rock fill in toe and for rip rap, 1,500,000 cub. yds. ; total : 16,000,000 cub. yds.

Construction of the earth dam itself is expected to take at least three years and could take longer, depending on the availability of plant.

RIVER DIVERSION

This is being accomplished by excavating a channel in the rock on the left bank of the river and

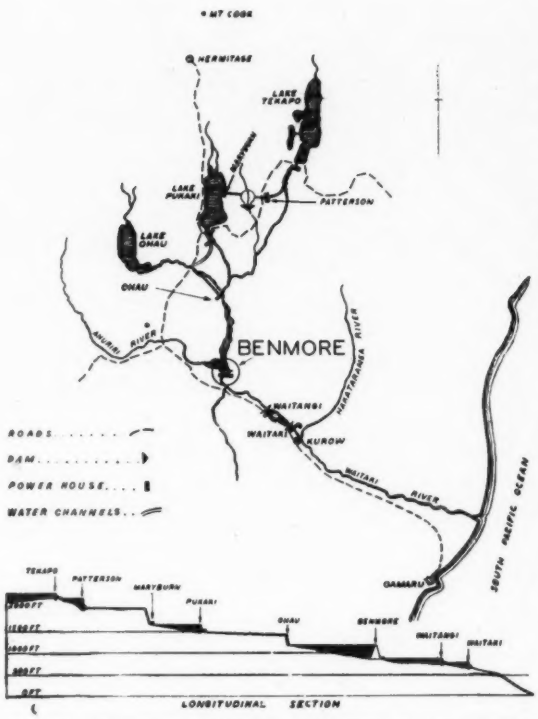

Fig. 3: Existing and proposed development of the Waitaki River Basin. Total capacity could exceed 1,500,000 kW.

subsequently constructing a twin-barrelled culvert. The internal dimensions of each culvert will be 25 ft. by 40 ft. and the two will carry a total maximum flow of 70,000 cusecs.

The river will be diverted at the upper end of the culvert by constructing a coffer dam across the river to a height of approximately 100 ft. Twin gates will be installed and when the dam is completed these will close off the river kow in the culverts which will subsequently be sealed off completely by concrete plugs.

Approximate quantities involved are : Excavation, mainly in rock, 450,000 cub. yds.; reinforced concrete, 120,000 cub. yds.; coffer dam fill, 500,000 cub. yds.

SPILLWAY

The siting of the project is particularly well suited to ensuring that floodwaters will be quickly and safely disposed of. A deep intake cut will be made through the rock ridge on the left bank to enable water to be discharged down the spillway and under sluices constructed in the adjacent gully. It will be thrown well clear of the toe of the earth dam.

The spillway is being designed to pass the 1 in 1,000 year flood of 120,000 cusecs at normal retention level. Sluices for partial dewatering will be constructed under the spillway and these will be capable of discharging a further 50,000 cusecs at the same levels.

Approximate quantities involved in the construction of the spillway and dewatering sluices are :— Excavation of overburden, 100,000 excavation of rock, 600,000 cub. yds.; concrete (including reinforced concrete), 150,000 cub. yds. Steel gates and equipment will weigh approximately 400 tons.

INTAKE AND PENSTOCKS

These are located on a spur on the right bank of the river which also forms the right abutment for the earth dam. The intake structure consists of a series of mass concrete blocks tthrough which the penstocks pass and then continue down the rock spur to the powerhouse below.

Quantities involved in the construction of the forebay intakes and penstocks are : excavation of overburden, 150,000 cub. yds.; rock excavation 450,000 cub. yds.; concrete (including concrete for penstocks), 100,000 cub. yds.

POWERHOUSE

The powerhouse is sited at the foot of a rock spur to which the penstocks are anchored and at a considerable distance from the present river. This will involve extensive tailrace excavation. However, as it is mostly in sands and gravels which will be used for the earth dam shoulders, the extra cost of providing such a tailrace is negligible.

A structural steel building with pre-cast concrete cladding, the powerhouse will be similar to Roxburgh but will be larger, the proposed length being 500 ft. Control buildings and outdoor station will be dependent on where the power from the station is to be transmitted.

Quantities involved in the construction of the powerhouse and tailrance, all approximate, are :— Excavation of overburden, 600,000 cub. yds.; excavation of rock, 200,000 cub. yds.; powerhouse substructure concrete, 50,000 cub. yds.; powerhouse area, 30,000 sq. ft.; control room area, 15,000 sq. ft.

PERMANENT VILLAGE

This will be sited on the western side of the present construction village adjacent to the Kurow-Omarama main road. The exact size of the village has not been determined but it will be at least as large as the present Roxburgh Village and there will be 30 to 40 houses.

PROGRESS ON CONSTRUCTION

The main emphasis on construction up to the beginning of 1959 was the establishment of the project. During 1959 there has been a constant direction of work to the dam site and speeding up of progress on the permanent works, in particular the diversion culverts. To date, approximattely £3,500,000 has been spent on the project.

Details of progress on the various phases of the work up to November, 1959 are :—

Diversion Culverts :

Excavation for the diversion culverts involved removal of some 450,000 cub. yds. of material, mostly rock. One third of this, in the form of wide bench cut into the rock ridge, was excavated during 1958. From January to July, 1959, the remaining 260,000 cub. yds. of cut excavation (excluding dumplings) were line drilled, shot and removed to the dam. This work involved some 270,000 lin. ft. of drilling and paddock blasting and the use of some 95,000 lbs. of explosive.

Clean-up of the diversion culvert using heavy air blasting equipment (5,000 cub. ft. air/min.), and concreting of the floor proceeded immediately and at the present time 36 out of the 48 floor panels have been concreted, 13,000 cub. yds. of concrete having been placed.

Twin movable forms for the arch sections are in place and concreting of the arch sections has begun.

Aggregate for most of this was supplied from a private contractor's aggregate plant which came into operation in September, 1959. The concrete has been batched in the Ministry of Works Johnson batching plant of four 2-cubic-yard mixers which was commissioned in August, 1959.

Main Dam and Coffer Dam:

The upstream coffer dam is now complete as far as the right bank of the Waitaki River and has involved the excavation of some 150,000 cub. yds. of river material and replacement of it by 40,000 cub. dws. of core material plus 120,000 cub. yds. of shoulder material. Further work on this coffer dam is now restricted to stockpiling until such time as the diversion culvert is completed.

For the main dam, rock from the diversion cut was all placed in the downstream toe. Further excavation from the spillway is now being added to this. Excavation of tthe foundations for the shoulders and for the main core trench has been proceeded with and some 110,000 cub. yds. and 100,000 cub. yds. respectively have been removed.

Spillway :

Excavation of the spillway area began in June,

Fig. 4: Progress on excavation of the diversion cut.

Fig. 5: Plywood-clad steel frame formwork to shape the interior of the arched diversion cutvert. Hinged at the top and mounted on rails, this form can be readily released from the hardened concrete and moved in to place for the next pour.

1959, and initially some 80,000 cub. yds. of overburden were removed. Rock excavation has been concentrating on "opening up" the site for large paddock blasting and during the past three months 60,000 cub. yds. of rock have been shot and removed.

Rock excavation is now continuing rapidly on a two-shift basis. Bulk excavation for the head and tail tower foundations is practically complete and the detailed work has been started.

Earthworks:

Preliminary stripping of the powerhouse, penstock and intake area began towards the end of September, 1959, and 100,000 cub. yds. of overburden and loose rock has been removed.

To November earth and rock work on permanent structures have involved the shifting of some 1,160,000 cub. yds. of material. Major equipment used on this work and the placing of the 13,000 cub. yds. of concrete mentioned previously, consisted of four 4-cub. yd. Marions used as shovels, dragline, or crane; eight 14-cub. yd. Euclids; twenty-one 10-cub. yd. Euclids; sixteen D8 tractors; two T.D. 24 tractors; ten wagon drills and ten scraper units of 15-20 cub. yd. capacity.

Site Services:

At the dam site, considerable effort has gone into the production of air, electricity, water and concreting services for existing and future works.

A compressor house with stationary comperssors is capable of supplying approximately 4,000 cub. ft. of air per minute, and a further 3,000 c.f.m. is available from portable compressors. Electricity is available at the site from the Waitaki Electric Power Board's sub-station at Otematata and emergency power from diesels installed at the compressor house.

A water supply scheme to provide high pressure water over the whole dam site has been constructed. The 4×2 cub. yd. Johnson batching plant and cement silos used at Roxburgh have been reconditioned. They were completed for operation in August and have operated continually since then. Cement is brought from the railhead silos (filled by a tippler system) in trucks fitted with airtight tanks from which it is pneumatically pumped to the site silo.

In the industrial area adjacent to the camp, the following buildings have been completed:—Carpenters' machine shop and workshops, fitting shop and blacksmiths' shop, electricians' shop and offices, steel yard and facilities, timber yard, store, main plant repair depot, and a main store.

Village and Amenities:

A new township laid out in accordance with the best principles of modern town planning has been built to accommodate workers and staff at the project. Named Otematata, it is virtually a completely self-contained community with all the services required for a high standard of comfortable living.

Nearly 500 houses are so far occupied by married men and their families who have in many cases laid out their allotments attractively in lawns, flowers and vegetable gardens. Every house is electrically heated, with electric cooking facilities, and a hot water supply. The township as a whole is fully reticulated for electricity, water and sewerage. Streets and footpaths are being surfaced with bitumen and rock chips.

Community amenities include thirteen bright, attractive and modern shops providing a full range of goods, a maternity hospital, doctor and dentist surgeries, a large and growing school providing education up to University Entrance standards, a cinema said to be among the most modern in the South Island, a social hall, gymnasium, police, fire and ambulance stations, a post office and a licensed hotel.

Four churches have established themselves, and

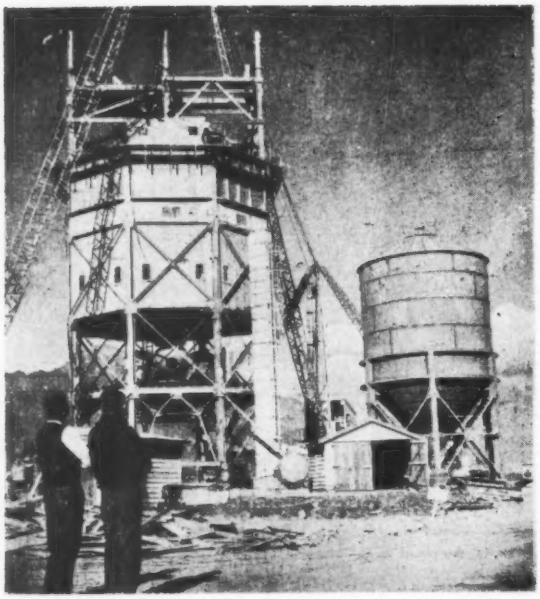

Fig. 6: The Johnson batching plant and site cement silo under construction. There are four concrete mixers, each of 2 cub.yd. capacity.

provision has been made for such sports as football, cricket, tennis, golf and bowls. A swimming pool will be constructed. Community enterprise has established a wide range of clubs catering for social activities from drama and photography to badminton, boxing, wrestling and the like.

Single men are accommodated in two large camps with a total of 450 individual huts. Each camp has its own kitchen and dining room block, and its own toilet block with provision for hot or cold baths or showers. There is a central canteen and social building operated by the Welfare Association.

This association is a body representative of all community clubs and activities. It also operates the cinema and plans to publish a weekly newspaper. All earnings are returned to welfare purposes, such as the purchase of additional sports equipment.

INVESTIGATION FOR FUTURE SCHEMES

As already indicated there is a total potential capacity of 1,500,000 kW in the Waitaki River development. This includes the 105,000 kW station at Waitaki, the 25,000 kW station at Tekapo and the lake control schemes at Pukaki and Tekapo which are already completed and in operation.

The Benmore project of approximately half a million kW is in course of construction. The remaining power potential of approximately 850,000 kW will be possible by developing two large stations at Ohau Bridge above Benmore, Waitangi below Benmore, and by three smaller stations at Patterson, Maryburn and Pukaki. The proposed layout of this development is shown in the accompanying illustration. (Fig. 3).

Survey of the Waitangi (Okaitu) area was started in 1925 and this has been enlarged upon. Over the past year exploratory drilling has been carried out to confirm rock levels and to determine the nature of over-burden. A more extensive pattern of drilling has been carried out and is now practically completed. This scheme will utilise the 125 ft. of head between Benmore and Waitaki.

The Patterson and Maryburn power schemes are based on diverting the 4,000 cusec flow from Tekapo across country in an open race and dropping the level to powerhouses at two convenient stages at the Maryburn Basin and at Lake Pukaki, thus utilising the available head of 700 ft. An aerial survey of the area has been completed and several trial layouts prepared. Detailed surveys of the alternative race lines, reservoirs and powerhouse sites are now being carried out and these are almost completed.

A further two schemes are planned at Pukaki and Ohau Bridge to utilise the combined flow of Tekapo and Pukaki and bring it in to Ohau. One development is proposed on the Pukaki River and the other at the present confluence of all three rivers at the head of the proposed Benmore Lake. Contour for aerial survey of this area has been completed and some preliminary ground contour plotting has been carried out along the Ohau.

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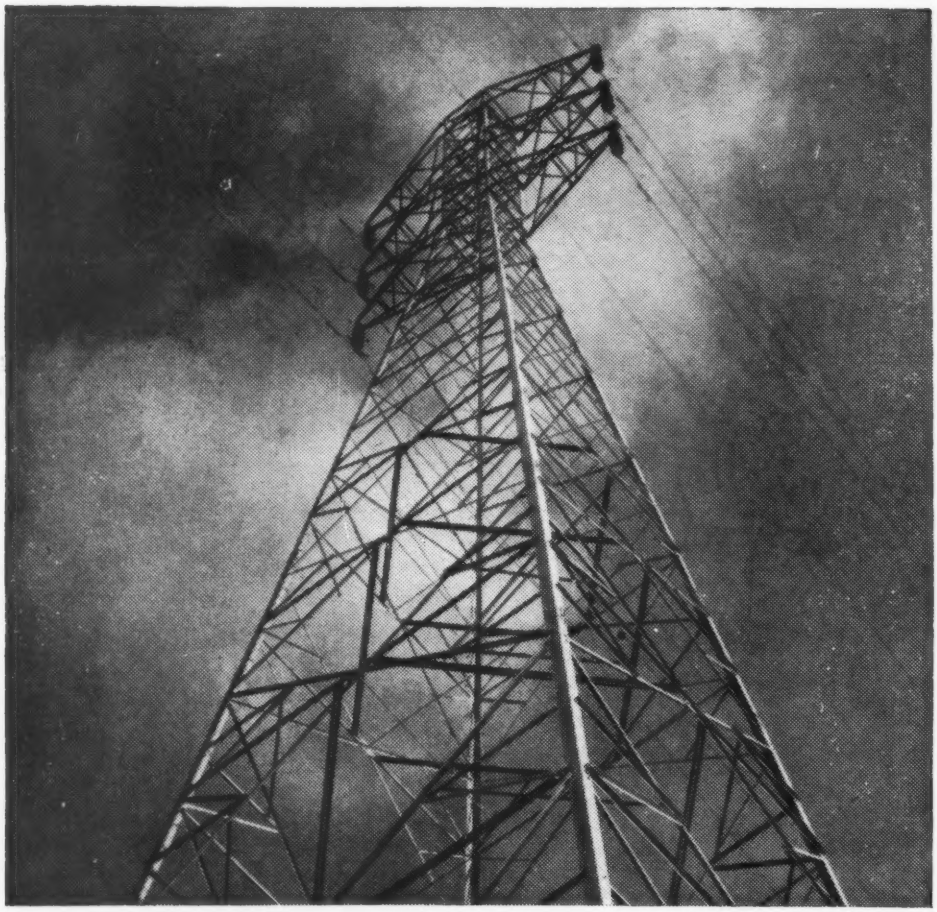

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Recent Developments in Extra High Voltage Power Transmission

By V. VENUGOPALAN

The definition of the expression "Extra High Voltage" in the Indian Electricity Rules, 1956, covers systems exceeding 33 kV. However, this term is generally applied in other countries to transmission systems above 230 kV. In this Paper, an attempt has been made to review the recent developments that have taken place in Europe and America in the field of power transmission at voltages above 230 kV.

SUPER STATIONS AND INTER-CONNECTIONS

2. The modern trend of power development in advanced countries is towards the construction of Super Power Stations of capacities approaching and even exceeding one million kW, closure of small, old and uneconomic power stations, transmission of large blocks of power at voltages exceeding 230 kV to distant load centres, and interconnection of adjacent power systems. A combined hydro and thermal grid network has a greater firm capacity than the sum of the individual systems operating in isolation. In such a combined system, the base load is carried by hydel power during monsoon periods and by thermal power during the dry season. The installed capacities of both thermal and hydel stations are used more effectively, thereby minimising standby generating units and effecting substantial economies in capital cost and maintenance. The frequency and voltages of interconnecting systems are less susceptible to variations on account of sudden changes in loads and fault conditions than in the case of isolated and small power systems. Key industries can be dispersed to suit the availability of raw materials, transport and utilization.

FACTORS GOVERNING HIGH VOLTAGE TRANSMISSION

3. The following factors cover the economics of the high voltage transmission :

(a) The load carrying capacity of a transmission line is proportional to the square of the operating voltage.

(b) The transmission line and terminal equipment costs rise rapidly with voltage, but more approaching the first power than the square.

(c) As a consequence of items (a) and (b), the investment cost of transmission decreases as the voltage increases, assuming that the full capacity of the line is utilised.

4. The economics of Super Power Stations have also resulted in the development of high voltage long distance transmission systems. The sites for power generation, both hydro and thermal, are usually far removed from the main load centres, and are determined by geographical conditions for hydro power and proximity to coal mining areas for thermal power. As regards nuclear stations, however, their location is not so inflexible as hydro and thermal stations, although it is the current practice to site them at places remote from thickly inhabited areas. Nevertheless, nuclear stations will also contribute towards long-distance high voltage power transmission on account of the large capacities and high load factors involved for economic power generation. Some examples of modern Super Power Stations are the Grand Coulee and the St. Lawrence Power Plants of about 1900 MW each, the Kitimat installation in Canada with 1700 MW, the American Electric Power Company's new Thermal Stations approaching 2000 MW, and the reported Russian Hydro Station of 4000 MW. The utilisation of these large blocks of power will necessarily involve long distance transmission lines of voltages exceeding 230 kV.

E. H. V. SYSTEMS

5. During the past 30 years or so, considerable progress has been made in the field of power transmission in Sweden, U.S.A., Canada, United Kingdom, France and U.S.S.R. Some of these developments are described below.

Sweden :

6. The hydro power sources in this country are concentrated in the north, while the power demands

are mainly in the south, with intervening distances of the order of 600-1000 miles. This has necessitated the construction of long distance high voltage transmission lines from the north to the south of the country. After the completion of six 220 kV circuits between 1936 and 1949, it was found necessary to go in for a higher voltage. In 1952, a 380 kV single circuit line, 600 miles long, was put into service from Harspranget to Hallsberg to transmit about 400 MW from the north to the south. This line has an intermediate switching station and interconnection with another power system of 800 MW capacity. Twin conductors and series capacitors have been used to improve the carrying capacity of this line. Since 1952, several extensions have been carried out at 380/420 kV, and there are about 1650 miles in this voltage class, which are either built or under construction, the planned total being 1900 miles. At present, 2500 MW are being transmitted from north to south over an average distance of 370 miles. The maximum demand for power transmission is estimated at 8000 to 10,000 MW over an average distance of about 500 miles. Possibly nuclear power stations will be installed to cover the basic loads in south Sweden, the planned capacities being of the order of 1000 MW. Although investigations have shown the economic advantages of a higher voltage of 650 kV for the loads and distances involved in Sweden, the advantages seemed to be too small to justify the adoption of a new voltage level above 400 kV. Consequently, it has been decided that the 400 kV level may be maintained and certain lines subsequently changed over to 500 kV.

U.S.A.

7. In the U.S.A., there are extensive transmission systems operating at 220-287 kV, the highest voltage of operation being 345 kV. The use of 345 kV as a primary transmission voltage is increasing rapidly with a total of 2400 circuit miles in operation and under construction. All the 345 kV lines now in operation utilise one conductor per phase. There are plans for 345 kV lines utilising two conductors per phase over a total distance of about 620 miles. For power development in the western States, the Bureau of Reclamation envisages a 500 kV grid. It is predicted that the total United States production of electrical energy in 1977 would be in the range of 1700 to 2700 billion kWh, the installed generation about 600 million kW, and the transmission capacity about 1.5×10^{10} ($kV^2 \times$ miles). It is anticipated that there will be continued and rapid expansion of extra high voltage systems at 345 kV and that a higher voltage of tthe order of 460 kV may be introduced by about 1962, and a still higher voltage of the order of 650 kV by about 1975.

Canada :

8. The highest voltage of operation in Canada is 360 kV. There are about 330 miles of line at this voltage with two conductors per phase. The Aluminium Company of Canada has planned about 190 miles of 345 kV line.

United Kingdom :

9. An extensive 132 kV grid system has been in operation in this country since the early thirties. A Super-grid system at 275 kV comprises over 500 line miles. By 1960, this line mileage will go up to 1700. In order to meet the growing demand for power, the super-grid system at 275 kV has been planned with some sections designed for eventual operation at 380 kV. It is proposed to instal nuclear power plants totalling about 5000 MW in areas deficient in coal production. These will be sited in localties remote from the centres of population in order to minimise possible radiation hazards. The nuclear power stations may be connected direct to the 275 kV network.

France :

10. The principal thermal stations are situated in the Parisian region, the collieries in the north and south of France, and the hydro stations in the Alps, Pyrenees and the Masif Central. An extensive transmission system has been developed for covering the entire country and interconnecting the hydro and thermal stations. By 1958, the transmission system had a total of 13,000 miles of lines, half on 225 kV and half on 110 kV. Development of hydro power in the Alps and Masif Central brought with it the problem of designing and building 225 kV lines which could be converted to 380 kV. The first conversion of a 280-mile link between the Alps and Paris from 225 kV double circuit to 380 kV single circuit took only two months and has stepped up the capacity from 350 MW to 550 MW. The total planned length for a similar conversion is 775 miles. A total of about 1800 miles will be in operation at 400 kV ultimately.

U.S.S.R. :

11. The first 400 kV transmission system from Kuibishev to Moscow, 800 km long, was put into operation in 1956. This was the highest voltage in Russia until the commissioning of the Stalingrad-Moscow 1000 kM line at 500 kV in December 1959. This line was constructed in two years time. The first stage of a scheme providing for development by 1960 of a consolidated power system in the European sector of 30,000 MW capacity entails the construction of 5000 km of 400 kV lines with 17 substations, in addition to 500 km of 800 kV D.C. lines. The second stage, which would increase the capa-

city to 50,000 MW or 60,000 MW, envisages the addition by 1965 of 6000-7000 km of 400 kV lines and 25 sub-stations. The change-over from 400 kV to 500 kV has been achieved in Russia by using the same towers and sub-station structures and changing only the auto-transformars, thereby achieving 40% more transmission without entailing appreciable additional capital outlay. By 1962, it is proposed to change over the entire 400 kV system to 500 kV in the European sector. In transmitting power blocks of the order of 650-700 MW and more per circuit over a distance of 800-1000 km, a line voltage of 500 kV will reduce the cost of power transmission by 4-9% with respect to 400 kV. Studies are on hand for D.C. and A.C. transmission of the order of 4000 MW over 1500-2500 km. In the Asiatic sector of U.S.S.R., transmission probblems involved a load of the order of 2000 MW over a distance of 2000 km. In Siberia, it is contemplated to adopt 600/660 kV for A.C. transmission. Problems of power transmission over 600 kV and designs of equipment for 600 or 750 kV operation are under studies. Direct current transmission up to 1000 kV is also under investigation.

Germany:

12. In Germany extra high voltage transmission at 400 kV is being employed to provide a high capacity backbone superimposed on an increasingly inadequate 220 kV grid that interconnects the hydro plants in the Alps with coal and lignite plants scattered from the Alps to the North Sea. In October 1957, one circuit of the 340 km long Rommerskirchen-Hoheneck 380 kV line was put in operation. The cost of the 380 kV line and stations was only 75% of the cost of a 220 kV system designed to carry the same amount of power. A further reduction of 15% is expected from recent progress in the design and construction of 400 kV systems. Current plans envisage a total of 1270 route miles of 400 kV double circuit lines inclusive of those in service and under construction.

Other countries:

13. Apart from the countries mentioned above, Finland and Czechoslovakia have also 400 kV systems in operation and under construction. In Finland, 600 miles of 380 kV lines will be in operation by 1960. In Rhodesia, 860 miles of 330 kV lines are nearing completion. Brazil will have 682 miles of 380 kV line by 1962. Australia has constructed 235 miles of 330 kV lines, the planned total being 800 miles.

E.H.V. LINE DATA

14. Table I summarises the main technical characteristics of some typical extra high voltage transmission lines which have been recently constructed and are nearing completion in various parts of the world. Table II gives the mileages of extra high voltage lines which are planned for construction in some advanced countries of Europe and America.

SUPER STATION EQUIPMENTS

15. Side by side with the rapid expansion of extra high voltage transmission facilities, significant developments have also taken place as regards the design and manufacture of extra-large sizes of steam turbines, waterwheels, generators, transformers and circuit breakers. Steam tur-generators of 500 MW capacity are planned in the U.S.A. by 1960, and 550 MW in England by 1962. It is reported that 600 MW units are under study in the Soviet Union. The maximum rating of 3-phase 2-winding transformers manufactured in USA is 375 MVA; 405 MVA units are being built, and 500 MVA units are declared to be feasible. Three-phase auto transformer banks of 600 MVA have been installed in a 345 kV system in the USA. In Germany, the 400 kV system has banks of 660 MVA auto transformers. Sweden is planning to instal in 1960 a bank of auto-transformers of 900 MVA output on the 400 kV system. Circuit breakers of 25,000 MVA rupturing capacity have been in service for several years on the American Electric Power Company's 345 kV system. Circuit breakers of the same capacity are being planned for the Russion 500 kV system.

TOWER DESIGNS

16. Extra high voltage lines have large mechanical loadings on supports because of bundle conductors, large air and ground clearances, considerable dynamic forces due to broken conductors, etc. Fabricated steel towers have been mostly used in all parts of the world as supports for Extra High Voltage lines exceeding 230 kV. The cost of the steel structure constitutes a major item of the total cost of a transmission line. Experience in the Bonneville Power Administration indicates that the cost of the structure ranges from 49 to 55% of the total cost of the line, covering both single circuit and double circuit construction for 230 kV, 287 kV and 345 kV lines. This percentage averages about 31-35% in the case of similar lines of the British Columbia Engineering Co. in Canada. It will be seen from thse figures that continued design refinements are necessary for bringing down the cost of E.H.V. transmission lines.

17. Subject to transmission requirements, double-circuit construction is adopted in preference to single-circuit lines in order to keep down capital costs and minimise right-of-way requirements. Since these transmission lines are extremely sturdy in construction and can be made practically lightning proof, the disadvantages of double-circuit construc-

TABLE I

CHARACTERISTICS OF EHV TRANSMISSION LINES RECENTLY BUILT AND NEARING COMPLETION
(275 kV A.C. and above)

Sl. No. (1)	System (2)	Voltage		Length		Phase conductors			Minimum Phase Separation. (10)	Line Insulation level.** (11)	Surge Impedance Load. (12)
		Rated (3)	Maximum (4)	Built (5)	Planned total (6)	Number (7)	Overall Diameter (8)	Total Area (alum.) (9)			
		kV	kV	miles	miles		inches	× 1000 cir. mils.	feet	kV	MW
1.	Bonneville Power Adm., USA.	287	302	230	1370	1	1.38	1,272	26.5	1300	210
2.	Quebec Hydro-Electric Commission, Canada	287	315	620 (D)	1065 (D)	1	1.38	1,272–1,361	24.7	1500	2 × 225
3.	Great Britain*	275	300	511 (D)	1700 (D)	2	1.13	1,690	25.4	1500	2 × 240
4.	AEP—OVEC—Common-wealth Edison Company, USA.	345	362	1043 (D)	1343 (D)	1	1.60–1.75	1,275–1,414	21.5	1450	2 × 300
5.	Rhodesia †	330	362	862		2	1.062	1,500	37.5	1520	378
6.	Sweden	380	420	1655	1910	2	1.25	2,070	39–36	1600–1400	517
7.	U.S.S.R.	400	440	1740	3500	3	1.19	2,850	36–30.5	1800	640
8.	Germany	380	420	210 (D)	1270 (D)	4	0.855	1·860	23	1800	2 × 632
9.	France ‡	380	420	280	775	2	1.04	1,280	47.6	1650	504
10.	Finland §	400	420	575	810	2	1.295	2,250	36	1590	525
11.	U.S.S.R.	500	525	600	4840	3	1.19	2,850	36	1800	905

* Planned for conversion to 380 kV.
† Under construction.
‡ Converted from two 220 kV circuits.
§ Some of these lines are operating at 230 kV.
(D) = Double-Circuit.
** Impulse with stand voltage including rod gaps where present.
Note : (1) In all systems phase configuration is horizontal for single circuit and vertical for double circuit towers (except in Germany where Double-Circuit delta is employed).
(2) For bundle conductors, spacing generally ranges from 16 to 18 inches.

TABLE II

PLANNED NEW EHV SYSTEMS
(275 kV A.C. and above)

Sl. No. (1)	Country (2)	Line Voltage		Total Length. (5)
		Rated (3)	Maximum (4)	
		kV	kV	kV
1.	United States	345	362	621
2.	Norway	275	300	232
3.	U.S.S.R.	330	362	4,340
4.	Great Britain	380	420	1,275 (D)
5.	Italy	380	420	70
6.	Argentine	380	420	600
7.	Sweden	500	525	310

(D) = Double-circuit.

tion which are generally valid for lower voltage lines do not hold good in the range of voltages of 230 kV and above.

18. In areas where the isoceraunic level is low, the Bonneville Power Administration have dispensed with overhead ground wires except in the immediate vicinity of line terminations for the protection of the substation equipment. Successful operating experience with fast reclosing breakers have justified the elimination of overhead ground wires in such cases, thereby effecting significant reductions in line costs.

19. Figure 1 shows the rotated base type towers which are in use on the Bonneville Power Administration's 345 kV lines. As a further refinement, they have developed a new type of 345 kV single circuit and double circuit towers which are much

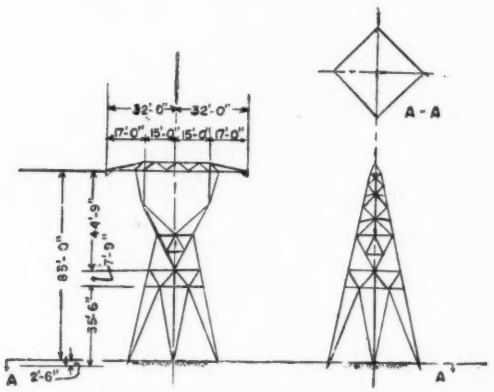

FIG. 1. BPA 345kV. LIGHT TOWER (ROTATED BASE TYPE)

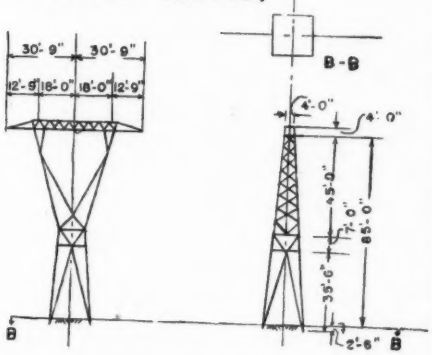

FIG. 2. BPA 345kV LIGHT TOWER (NON ROTATED BASE TYPE)

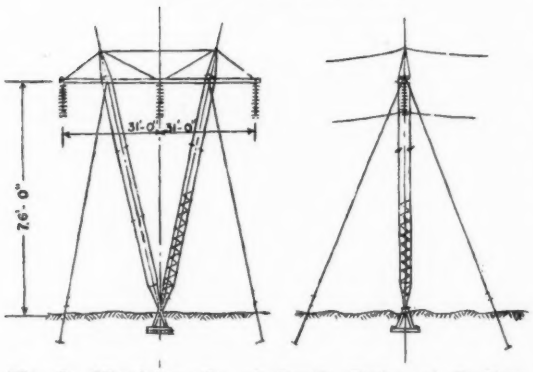

Fig. 3: Alluminium Co. of Canada Design of V—Type Tower for 345 kV. Line.

slimmer at the waist and have a narrower and square (non-rotated) base. This type of design is shown in Figure 2. The anticipated savings in tower weight range from 15 to 20% for single-circuit lines and about 10% for double-circuit lines by adopting this modified design.

20. By adopting relatively low values of maximum working tension of power conductods (about 35% of ultimate strength), the Bonneville Power Administration have eliminated the need for installing vibration dampers on all spans. A careful study of the terrain and prevailing winds is made along the route of each line and areas selected which need vibration protection.

21. The choice of steel-cored aluminium condustors for extra high voltage lines with particular reference to the proportion of aluminium and steel sections is made in conjuction with the design of steel structures so as to ensure a co-ordinated and economical design of the transmission line as a whole.

22. The use of high tensile steel for leg members and bracings subjected to heavy loadings has been adopted by several countries with a view to reducing the total weight of steelwork, thereby effecting economies in transport, handling and erection. The tower designs adopted by the Bonneville Power Administration employ high tensile steel to the extent of 20 to 35% of the total weight. The designs of 360 kV towers adopted by the British Columbia Co. in Canada cover 45-75% of high tensile steel. Composite designs using standard structural steel for lightly loaded members and high tensile steel for heavily loaded members have also been adopted on several transmission lines of 66 kV-132 kV in India and other countries. The Aluminium Company of Canada have developed a new design of V type tower with members fabricated in aluminium instead of steel (see Figure 3). They are planning to install four towers of this design in one of the 345 kV circuits envisaged from Chute-des-Passes Hydro development to the existing Saguenay Power System. It is estimated that this tower, if fabricated in aluminium, would cost approximately 45 to 60% of the conventional square base type in steel sanctions. The estimated weight of this design in aluminium is 2400 lbs only, as against the conventional steel tower weighing 13000 lbs.

23. For all extra high voltage lines in the Soviet Union, suspension towers are designed on the basis of normal operating conditions only. The use of releasing clamps, clamps with limited holding capacity, deforming crossbars, and also the combined use of dead-end and slip clamps, facilitate the alleviation of the forces on suspension towers for breaks in conductors. For the first 400 kV lines in the Soviet Union, releasing clamps were used which were designed for a three-conductor bundle. The drawback in using releasing clamps is that they drop the conductors to the ground, thereby necessitating the use of strain towers every 7-10 km. Strain towers would not be needed if releasing

clamps could be replaced by clamps of another design which would limit the force on the suspension tower for breaks in conductors without their falling to the ground. Several designs of such clamps are being subjected to tests on experimental line sections and are likely tto be used on future E.H.V. lines.

INSULATION

24. The level of line insulation for a given voltage rating has been taking a downward trend in recent years, the main reasons being the use of high speed reclosing breakers, which has decreased the relative importance of line faults due to lightning, and the reduction and control of switching over-voltages by the use of modern relay-breaker systems.

25. Overhead ground wires are sometimes omitted in the regions where the incidence of lightning is low. This is the practice in the north-western areas of U.S.A. In all other areas in America and in most other countries, groundwire protection continues to be the practice for E.H.V. lines. The overhead groundwire, the line insulation, and the tower footing impedances are carefully co-ordinated to attain good lightning performance of the line in accordance with the well-established curves based on the stroke current theory of lightning discharges.

26. In the Soviet Union, the protection of transmission lines against lightning is achieved by means of groundwire and automatic reclosing. Almost all the lines above 150 kV (99%) are fitted with automatic reclosing devices. Good earthing of supports and use of earthwires with protective angles between 20° and 30° have shown good operating results. The insulation for the lines and equipment of 400 kV transmission systems in the Soviet Union is designed on the basis that the neutral of 400 kV power transformers is solidly grounded; the transmission line is protected along its whole length from direct lightning strokes by two ground wires providing a protection angle of 15-20°; the tower footing resistance is up to 10 ohms; and the substations are protected by rod gaps and valve lightning arresters.

27. Reduction in transformer insulation by one step in the Basic Impulse Level for effectively grounded neutral systems is rapidly becoming the standard practice in the U.S.A. at voltages of 115 kV and above. reduced insulation by two steps is expected to prevail in future E.H.V. systems. Transformer basic impulse insulation levels of 1,425 and 1,925 kV appear to be possible for 460 kV and 650 kV systems respectively.

CONDUCTORS AND LOADING CAPACITIES

28. The problems of corona loss and radio disturbance become more significant as the transmission voltage is increased to higher levels. In the early decades of high voltage transmission, the corona problems was controlled by using steel cored aluminium conducttors of adequae overall diameter and in some cases by means of special 'expanded' construction of copper conductors. As radio broadcasting developed increasingly in areas covered by networks of power transmission lines, radio disturbance became a more critical factor than corona for high voltage lines. It was found economically possible to use single-conductors per phase for high-voltage lines up to 230 kV (and even for higher voltages in some cases) and yet keep corona and radio influence within permissible limits. For Extra High Voltages above 230 kV, multiple conductors per phase appear to be the only economical solution and are being mostly used in all parts of the world.

29. The use of multiple conductors per phase makes possible a significant reduction in the maximum surface electrostatic field of the conductors. Corona initiation voltage increases over that of a single conductor of the same cross section, thereby reducing the corona loss and minimising radio disturbances. Multiple conductors also reduce the line reactance, and consequently higher loadings are possible.

30. The following table gives the surge impedance loadings per circuit for respresentative voltage levels with single and multiple conductors.

Line voltage (kV)	**Surge Impedance Loadings in Mw.*			
	Single Conductor	*Twin Conductor*	*Triple Conductor*	*Quadruple Conductor*
1	2	3	4	5
110	30			
132	44			
161	65			
230	132	165		
287	206	258		
345	297	372		
400	400	500	570	615
460	530	662	756	815
650	—	1320	1510	1620

* Surge impedance values assumed are 400, 320, 280 and 260 ohms for single, twin, triple and quadruple conductors respectively.

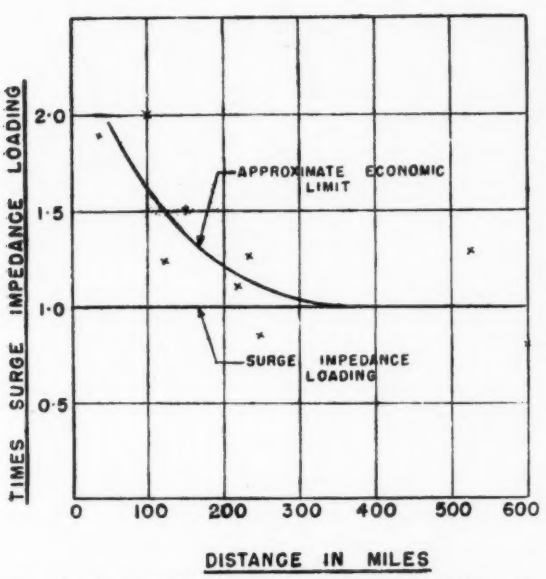

Fig. 4: Approximate Transmission Economic Loading in Terms of Surge Impedance Loading.

NOTE: Loadings of some important E. H. V. systems are indicated by cross marks.

31. On the German 380 kV system with four 21.7 mm dia. conductors per phase, corona losses are reported to be insignificant. A minimum of three conductors per phase would be required at 500 kV and four at 600 kV. Experience has shown that the adoption of multiple conductors would considerably reduce the Radio Influence Voltage to generally acceptable levels. With a conductor size from 1.75″ to 2″, voltages close to 1000 kV are possible with quadruple conductors per phase.

32. In Sweden, the use of two conductor bundle for their 220 kV transmission lines has shown that, while the cost is increased by 21%, the power capability is increased by 30%, thus resulting in a net overall decrease in the cost of power transmission. However, multiple conductors for 230 kV lines may not be essential in all cases, the benefits being in the marginal range.

33. In the case of E.H.V. lines above 230 kV, the use of multiple conductors is to be preferred, the advantages being more pronounced for higher voltage levels.

34. Fig 4 shows a curve indicating the approximate economic capability for power transmission in terms of surge-impedance loadings. Present E.H.V. systems operate more nearly approaching the economic limits. Loadings of some important E.H.V. systems are indicated by cross marks in this figure.

PROBLEMS AND INVESTIGATIONS

35. Although several technical problems have been solved in the past in respect of E.H.V. systems, the rapid expansion of these facilities and especially the transition to higher voltages in the 460-650 kV range are continuously posing many additional problems which are engaging the attention of experts in various countries of Europe and America. Extrapolation of present practices is not always adequate, and novel solutions will have to be devised in a number of cases. Some of the important problems involved are system design, line design, apparatus design, and evaluation of their performance under service conditions.

36. The solutions of the problems involved in E.H.V. transmission are being obtained by means of analytical studies, laboratory investigations, experimental lines, and prototype systems.

37. Exerimental lines are a valid representation of the performance of future E.H.V. lines and have been the favourite method for solving in advance problems of E.H.V. transmission. These experimental lines have been built, since World War II, in many countries which have utilised system voltages exceeding 230 kV.

38. 500 kV three-phase experimental lines were built at Chevilly (France), Rheinau (Cermany), Tidd (Ohio, USA), and Leatherhead (England), for comprehensive tests on corona and radio influence. Many other experimental lines of 500 kV and below, single and three phase, have been built to study the effect of higher altitudes, sleet and icing phenomena, and mechanical performance.

39. Single phase lines of $600/\sqrt{3}$ kV have been built at Gotheborg (Sweden). U.S.S.R. has single phase lines of $650/\sqrt{3}$ kV at Leningrad. Canada had plans to have 600 kV three-phase line by 1959.

40. In U.S.A., France and Canada, some experimental lines are carrying power as part of an operating system. General Electric Company have planned a prototype E.H.V. system (750 kV) near Pittsfield (Massachusetts, USA) by 1960 to investigate system performance from 400 to 750 kV and thus obtain satisfactory solutions to the various problems which must be solved in order to make future E.H.V. transmission feasible, reliable and economical.

DIRECT CURRENT POWER TRANSMISSION

41. Direct Current offers certain inherent advantages over Alternating Current for transmission

of large blocks of power over long distances. This has prompted a number of countries, notably the Soviet Union and Sweden, to carry out extensive investigations on this subject.

42. The following are the main advantages of D. C. transmission :

(a) Lower line costs and high circuit loadings.

(b) Elimination of KVAr transfer due to unity power factor characteristics.

(c) The power capacity per circuit on D. C. systems is not limited by surge impedance loadings, and there is no limit for the length of tranmission line on grounds of stability.

(d) The performance of a D. C. tie between relatively large power systems could be made independent of external conditions such as fault disturbances.

(e) The D. C. system is essentially free from inertia effects due to mass inertia characteristics of rotating A. C. machinery.

(f) The natural dielectric strength of cable insulation is substantially greater in D. C. than A. C. applications.

(g) Proximity, skin and inductive effects are eliminated. The consequent elimination dielectric loss and charging current heating should permit a significant increase in permissible load rating and therefore greater power transmission capability, which should give underground D. C. transmission a substantial advantage over underground A. C. transmission.

(h) Unlike A. C., D. C. corona does not produce any harmonics causing interference with adjacent telecommunication circuits.

43 The advantages of A. C. transmission are lower terminal equipment costs, inherent flexibility, and proven reliability of A. C. systems over the past several decades.

44. There are various problems encountered in D. C. transmission. The converting equipment is expensive and is still in the course of development for large-scale commercial use. At present operational difficulties are encountered with converters and inverters. Reliable D. C. high voltage circuit breakers have yet to be developed.

45. On an A. C. line, intermediate loads may be supplied by adding a relatively inexpensive substation at the desired location on the line. If a D. C. line is to supply an intermediate load, a complete inverting station must be added, which will be much more costly than an A. C. substation to supply the same load. The D. C. station should include not only the transformer and switchgear capacity of A. C. station but also the equipments to convert the D. C. power to the A. C. load requirements.

46. D. C. overhead transmission may require relatively large conductors in order to insure a reasonable power transmission efficiency and line voltage drop and provide an optimum combination of the cost of decreased losses and increased line costs. Studies on conductor size show that the total conductor weight for a two-pole high voltage D. C. system is of the same order of magnitude as that of a three-phase A. C. system.

47. The following table gives the approximate economic loading range for typical D. C. voltage levels and for different transmission distances :

APPROXIMATE ECONOMIC LOADING RANGE

D.C. Voltage	±100 *kV*	±200 *kV*	±300 *kV*	±400 *kV.*
Miles	←- - -	*Megawatt per circuit*	- - - →	
200	100-200	300-800	575-1500	⩾ 950
300	100-200	350-800	⩾650	⩾1,100
600	120-200	400-800	⩾800	⩾1,300

48. Comparative studies of annual costs show that the economic voltage choice for D. C. transmission will depend directly on the circuit loadings. For loads of 100-175 MW per circuit, ± 100 kV gives the minimum annual cost ; circuit loadings of 175-500 MW would call for ± 200 kV ; loads of 500-1000 MW would require ± 300 kV ; and for loads over 1000 MW per circuit ± 400 kV or higher voltage levels would be desirable. The choice of voltage level is predominantly dictated by circuit loadings, and distance has a minor effect on the economic choice of voltage level. This is in contrast to A. C. overhead transmission, wherein the effect of distance is more significant.

49. D. C. transmission has so far found practical applications for transmitting power by cable—viz., the existing 100 kV submarine link from the Swedish mainland to the Island of Gotland, the planned 200 kV cross-channel link between France and England, and the underground 200 kV line operating between Moscow and Kashira. The Swedish 100 kV D. C. submarine link was put into

operation in 1954, these transmission capacity being 20-40 MW. The French-English submarine cable (about 32 miles in length) will transmit 160 MW at 200 kV. Moscow-Kashira 67-mile 200 kV line with two single-core underground cable transmits 30 MW. For overhead power transmission, D. C. is being actively investigated at present only in the Soviet Union, which is now building a ± 400 kV link, 500 km long, between Stalingrad and the Donbas to transmit 750 MW. It has been stated that this link will cost more than a comparable A. C. line at 400 kV or 500 kV, but it is being built to gain experience with D. C. transmission.

50. For the extension of the Swedish lines, system comparisons were made of 650 kV A. C. lines with ± 400 kV D. C. lines for an economic loading of 1500 MW. The cost per mile of the D. C. line was estimated at 60-65% of that of the A. C. line. The cost of the D. C. terminal stations was assumed to be only 100% greater than those of the A. C. stations, but even then it was found that the two systems would compare favourably for a minimum distance of the order of 400-450 miles. There are no plans at present in Sweden to construct new D. C. lines.

51. D. C. overhead transmission appears to be economically feasible and shows a margin in annual transmission costs over A. C. systems for transmission of large blocks of power for very long distances. For a loading of 300 to 400 MW, a minimum transmission distance of 400 miles would be required in order to offer any possible economic advantage. D. C. overhead transmission wil probably not be widely utilised as long as economic factors are the governing consideration. Where factors other than economic enter the picture, D. C. could conceivably be developed. System growth and inter-connection requirements foreshadow the development of higher voltage A. C. systems with increasing area of interconnections because of the flexibility and proven reliability of high voltage A. C. systems. D. C. transmission may supplement A. C. transmission rather than compete with it. D. C. transmission can be practicable and even be the only possible and economical solution, when the transmission is done through underground or submarine cables.

STANDARDIZATION OF SYSTEM VOLTAGES

52. The desirability of evolving standard system voltages was recognised by the International Electro-technical Commission as early as the twenties. In 1927, the Commission issued Publication No. 38 on standard system voltages for consideration and adoption by all the countries of the world. This Publication was revised in 1938 and again in 1954. Since various system voltages had been adopted by the countries in Europe and America and a change-over would be difficult in most cases, the International Electrotechnical Commission had to incorporate several voltage standards in common use. The following table gives the values of the nominal and the highest voltages of three phase systems of 60 kV and above, as recommended in IEC Publication No. 38 of 1954. The values standardised by the British and Indian Standards Institutions are also given side by side.

Nominal Voltage (kV)			*Highest Voltage (kV)*
IEC Pub. 38 of 1954	*BS 77 of 1958*	*IS : 585 of 1954.*	
60, 66, 69	66	66	72.5
80, 88, 90	88		100
100, 110, 115	110		123
120, 132, 138	132	132	145
150, 161			170
220, 225, 230	220		245
275, 287.5	275		300
	330		360
380	380		400

53. The International Electrotechnical Commission are currently examining proposals for introducing an intermediate voltage level between 275 kV and 380 kV, and also one or two steps above 380 kV. Proposals for standardising voltages for D. C. transmission are also under consideration in collaboration with proposals for standardising the voltages of rectifier sets.

54. The author hopes that the material presented in this Paper will be of some use to the Engineers in this country in planning the power systems not only to meet the anticipated needs within the next few years but also to fit in with the pattern of development in the not-too-distant future.

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[*Continued on page 32*

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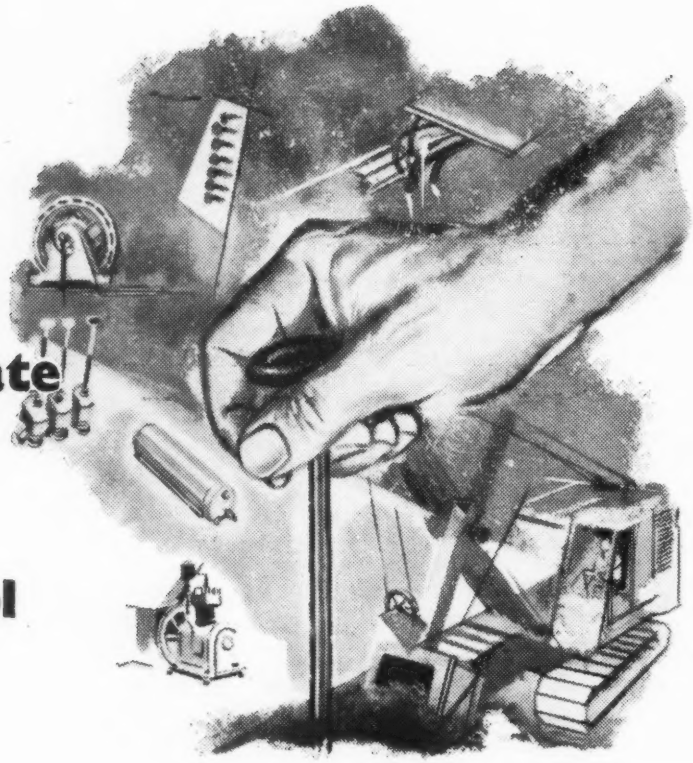

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Soil Mechanics & Foundation Engineering

BALESHWAR NATH

Soil Mechanics is a basic practical aspect of theoretical applied mechanics, and runs through all the branches of civil engineering, including construction of buildings, highways, dams and embankments sewage and water works, railways, construction of hydraulic structures, aerodromes and defence installations. In actual field operations, its principles are closely linked with foundation engineering practices, followed in different disciplines of engineering profession. Combined study of Soil Mechanics and Foundation Engineering, therefore, presents a composite picture for scientific treatment of this important aspect of engineering investigations, research and practical field experimentation. It calls for close collaboration at national and international levels. That in short, is the genesis of the International Society of Soil Mechanics and Foundation Engineering, which has among its chief objectives promotion of international co-operation among scientists and engineers in the field of soil mechanics and its practical application. Its Indian component, the Indian National Society of Soil Mechanics and Foundation Engineering was formed in 1947 with Dr. A. N. Khosla, presently Member Planning Commission, as its first Founder President.

Among the nations of the world, which put soils to extensive use in building up of dams, embankments pathways, and even human habitations, India and China were probably the first. Soil mechanics was thus engineered into action, ever since man developed his environments, apart from the fact that the very formation of lands, both on the coastal regions and in the alluvial plains, has mostly been caused through gradual movement of soils from hilltops into river basins with the currents of flowing water. As early as 2nd century B.C. Cholas in the South India executed a great engineering work across the Cauvery, to divert its water for irrigation of deltaic areas. Similarly, the great Bhojpur lake in Betwa basin 20 miles south of Bhopal was created by suitable earthen bunds. This lake was more than 100 feet deep at certain places. Again, in the inscriptions giving technical details of construction during Vijayanagar dynasty in the 14th century, mention has been made of six 'doshas' or defects in design and construction of works. Two of these defects have close bearing on the technique of soil mechanics and foundation engineering. They pertain to the theory relating to percolation of water from under the bunds and to salinity of soils in irrigated areas. Though the ancients were aware of the construction of soil structures and of behaviour of soil in foundation constructions, a mathematical analysis and systematic approach on scientific basis had apparently, not till then been evolved.

A probe into the history of Soil Mechanics reveals that first attempt in this direction was made in the 18th century by a French engineer named Coulomb in 1773. He propounded his Wedge theory of earth pressures and critical height of clay banks. His theory still holds good. His formulaes are used even now. Further development in the science of Soil Mechanics proceeded ; and in 1840, Poncelet produced graphs for practical application of Coulomb's Wedge theory. Later, Collin in 1846 and Airy in 1879 continued investigations with regard to the stability of clay slopes, and they actually measured the shear strength of soils. In 1856, Darcy studied permeability of sands, and in 1857 Rankine examined the bearing capacity and earth pressures of sands. Boussinesq investigated distribution of stresses under loaded area in 1885. As a problem of general engineering interest, study of Soil Mechanics received continued attention through out the nineteenth century. An important development, however, took place in 1918 when Prof. Krey carried out active research in connection with the construction of Kiel Canal. He evolved stability analysis for foundations, retaining walls and earth slopes. Contemporarily, Bell investigated in Britain, the bearing capacity and earth pressures in clays. That in brief, portrays the attention given in the past to this important aspect of engineering studies.

C. A. Coulomb

A significant stride in the development of science of Soil Mechanics, however, was taken in

1924, when a Geo-Technical Commission under the Chairmanship of *Wolmar Fellenius* appointed by Swedish Government to study the causes of catastrophic landslides on Swedish State Railways, published their extensive report. This subject, primarily of geo-technical nature was, however, named differently in different parts of the world, till it was christened "Soil Mechanics" during the first International Conference of Soil Mechanics and Foundation Engineering held in USA in 1936. The Conference was organized by Professor Arthur Casagrande of Harvard University. A number of valuable papers were presented in the Conference. Subsequently, Prof. Karl Terzaghi, the most leading living engineer in the field of Soil Mechanics reviewed the subject in his J. Forrest Lectures at the Institution of Civil Engineers (London) in 1939.

Wolmar Fellenius.

Soil Mechanics is now well established as a basic engineering study. Broadly speaking it deals with stresses in soil and resultant effects. It comprises soils surveys, soil testing, interpretation of test result, their application to the use of soils in natural state and utilisation of soils as construction material These studies, when extended to the domain of foundation of engineering structures enable rational principles and practices to be evolved for guidance of field engineers. In the absence of such studies, the design tendency is to lean towards over-safety. That results in uneconomic constructions, whereas in the present age of rapid constructional development, a Civil Engineer is needed more than ever before to design his structures ever more economically, there being a general shortage of building materials and money. Foundations of modern high and heavy structures always involve a good percentage of constructional expenditure, particularly, on alluvial and hetrogenous soil formations. Great economics can therefore, be effected through proper study of soils and sub-soils, regarding such factors as shrinkage and swelling characteristics, bearing capacities, mechanical analysis, void ratio, natural moisture content, in situ dry desnity, plastic limits, organic matter content, unconfined compressive strength, triaxial and direct shear strength and permeability co-efficients. With the increasing knowledge in this field such studies are now replacing the old thumb rule criteria and are leading to more scientific and economic foundation designs than what had been possible in the past.

It is common knowledge that characteristics of a soil change with the quantities of water present in it. And incidentally, water is found mixed with soils in varying proportions according to prevailing weather and natural conditions and numerous man made limitations. This fact, therefore, gives rise to many problems. An engineer naturally seeks to ascertain, to what extent soil characteristics will get effected by a change in its moisture contents, which may subsequently take place. A firm soil when laid up with water becomes slushy. Again, clayey soils develop cracks on drying up. Sandy Soils retain firmness to an extent but become almost mobile in dry conditions. Soil-moisture relation is, therefore, a complicated question. On the other hand, all plant and animal life is concealed, more or less, in the miracle of soil and water. Understanding of this miracle in its various aspects and phases, including that in relation to Soil Mechanics and Foundation Engineering is, therefore, a mission worth pursuing.

Purely engineering aspect of Soil mechanics, however, is concerned with the properties of soil and its capacity to resist extraordinary pressures and loads. Varying stresses are induced in underlying soils when loads come over roads, railways, aerodromes, runways, bridges, dams and buildings of different kinds. Field test of such soils are, therefore, of paramount importance. If constructions are allowed to go without such tests, the results can be greatly concerning or even disastrous. Accounts of engineering works are full of instances, where actual failures have occured because adequate attention was not given to the study of underlying soils. Cases have been reported, where structures found on clayey strata got bodily tilted, because clay under pressure acts almost like a rubber pad. Again behaviour of running sands on which quite a number of hydraulic structures have unavoidably to be founded, is fairly treacherous. Special attention has therefore to be given to such soils, besides a close study of their varying properties like compressibility, flexibility, cohesion, porosity and permeability. As a personal experience the author once faced serious cracks in a huge hydraulic structure, because continuous subsoil pumping had been resorted to, on a lower level at a distance downstream. That apparently led to displacement of soil particles from under the foundations and cracks appeared. All such experiences serve as gerater pointers towards a comprehensive and concerted study of soils and their characteristics, including the mechanics thereabout.

Roads in these regions and even abroad, can not all be made concreted, metalled or tar-topped.

[*Continued on page 22*

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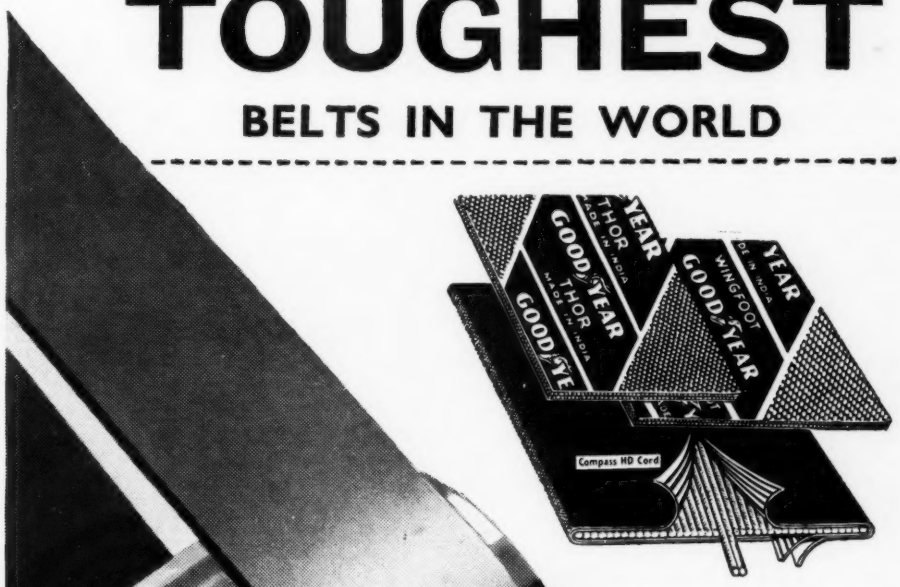

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Asian Conference on Soil Mechanics and Foundation Engineering

The following is a brief review of the first Asian regional conference of the International Society of Soil Mechanics and Foundation Engineering held at New Delhi during February 1960.

In pursuance of the statutes of International Conference of Soil Mechanics and Foundation Engineering providing that a regional conference be held during the period intervening between two International Conferences, the First Asian Regional Conference was inaugurated in New Delhi (India) by Shri Jagjiwan Ram, Union Minister for Railways on the February 4, 1960.

Dr. K. L. Rao, Vice-President of the International Society of Soil Mechanics and Foundation Engineering for Asian Region presided. Shri Jai Sukhlal Hathi, Union Deputy Minister for Irrigation and Power, Dr. A. N. Khosla, Member Planning Commission and founder President of the Indian National Society of Soil Mechanics and Foundation Engineering and Monseiur Armond Mayer, Vice-President of the International Society for Europe Region attended the session, along with many Engineers and Scientists from different parts of India and other countries, namely Israel, Japan and U.S.S.R. Shri Baleshwar Nath, Secretary, Central Board of Irrigation and Power was the organising Secretary of the Conference.

Expressing appreciation on the work carried out by different departments, laboratories and design organisations in the country in the field of soil mechanics and foundation engineering, Shri Jagjiwan Ram stressed upon the need of having a co-ordinating organisation so that Engineers and Scientists in the field could supplement each others efforts for achieving better progress in the important field of Soil Mechanics and Foundation Engineering. Towards such an object he suggested the formation of a co-ordinating semi-autonomous body in India, representing all engineering disciplines.

Dr. A. N. Khosla, the founder president of the Society, while welcoming the delegates from abroad and India, referred to the several problems relating to the stability of structures resting on permeable soils, which he had to face in early years of his professional career. He stressed upon the need of intensive study of the subject of soil mechanics for the solution of major foundation problems. He hoped that as a result of deliberations of the conference new ideas and new techniques will emerge, which will help in securing added stability, cutting down time and ensuring the most economic and efficient designs.

PRESIDENTIAL ADDRESS

Dr. K. L. Rao in his presidential address pre-

Left: Shri Jagjivan Ram, Union Minister for Railways (India) delivering inaugural address, Sitting (L—R) Shri Baleshwar Nath, Dr. K. L. Rao, Shri Jai Sukhlal Hathi, Dr. A. N. Khosla, Mr. A. Mayer, Right: A General View of the Assembly.

sented a brief review of the early contributions made in the science since 1773. He pointed out the main defect in earlier thinking on the subject lay in completely neglecting the properties of soils. He stated that Dr. Karl Terzaghi has since contributed greatly toward evolution of soil sciences and is the founder of the present phase of soil mechanics. Quoting Dr. Terzaghi, "The forecasts pertaining to the behaviour of cohesionless soils were essentially correct, where as in the case of clay, field behaviour and forecasts were different. Properties of undisturbed clays are more complex than laboratory tests. Energy natural clay stratum seems to possess a personality of its own due to conditions under which sedimentation took place and due to influence of chemical environment in which the aging occurred", he stressed that further development of science requires collection of field data so that the effects of (a) Heterogenous nature of soils (b) soil structure in position (c) lapse of time etc., may be studied in greater details.

Dr. Rao further stated that in some of the works in India like Hirakud Dam, which is perhaps the longest earth dam in the world being nearly 15 miles, Kotah Dam 120 feet high built on highly permeable substratum, approach embankments at Mokamah bridge, express highway near Bombay on marshy ground, cement concrete flexible pavement for roads in a new township near Bhopal, construction of Kandla Port on a soft and slushy area and extension work at other ports etc., soil mechanics is being employed extensively and great economies have been achieved. He also laid stress on the early establishment of private consultation laboratories with site investigation equipment, which have so far not been established in the country.

SUBJECTS OF DISCUSSION

Two subjects were selected for discussion at the Regional Conference. The were :

(i) Construction and Behaviour of Earthen Embankments, and

(ii) Foundations of structures other than Hydraulic Structures.

Fifteen papers presented on the first subject, covered the construction techniques of earthen embankment, field behaviour, defects and remedial measures, see page observations and measures to reduce the same and failure and causes thereof.

The twelve papers presented on the second subject covered site investigations and design of foundations, causes and effects of settlement and treatment of special soils.

Apart from the papers, selected for discussion, 10 papers were also presented as communication on soil properties and their measurement, including general soil stabilisation techniques and technique of field measurement and sampling.

CONSTRUCTION AND BEHAVIOUR OF EARTH EMBANKMENTS

The first subject "Construction and Behaviour of earth embankments" was presented for discussion by the General Reporter, Dr. R. C. Hoon, Director, CW. & PC. (India). Salient points as emerged out of the papers were :

(i) by providing a standing filter behind the impervious zone connected to the downstream by a horizintal drain at the base of the dam, the downstream slope would be dry and would reduce pore pressure even for the worst case of rapid drawdown.

(ii) In remodelling of old earth dams, attention of soil engineers has been drawn to two principles viz., the age of the old dam and the conciliation of differences in the engineering properties of soil used in the the old dam and that intended to be used in its remodelling.

(iii) From laboratory study, it is shown that for cohesionless material such as sand, instead of merely combining the optimum static load and vibration, if the static load and vibration, if the static load is applied in increments and sand vibrated after each increment, the density increases considerably and also it is observed that 100% saturation will yield densities as good as those under dry condition, if compaction by vibration is adopted.

(iv) It is also shown that using the relationship formulated by Rao (India) it will be possible to determine the compaction ratio in the same way as done by Hilf (U.S.A.) and the method offers further simplification of the experimental work involved in assessing soil compaction ratio.

(v) Though unconfined compression test has been considered useful for estimating stability of embankment, yet factors like time lag between the occurrence of the slides and collecting of test samples, taking of the mean values of the test results etc., seen to affect the results.

(vi) Analysis of excessive seepage in clay reservoir estimation of permeability has indicated greater effects of entrapped air in laboratory studies and thereby point out the importance of study of physico-chemical properties of soil, which is seldom taken into account in soil engineering.

FOUNDATION OF STRUCTURES OTHER THAN HYDRAULIC STRUCTURES

The general report on the second subject "foundations of structures other than Hydraulic sttructures" was presented by Mr. Kano Hoshino, Institute of Industrial Science, University of Tokyo (Japan). The General report brought out the following salient points :—

(1) A correlation between the swelling pressures in expansive clays and other soil properties has been presented along with the effect of width of foundation footing on swelling pressures.

(2) Handling of a weak compressible soil in the foundation by use of vertical sand drains which would effect quick settlement.

(3) Treatment of weak soils to improve their strength and other physical properties with some specific methods, such as silicate treatment of the soil by electro-osmotic process.

Besides, the delegation from U.S.S.R. presented three papers, which generally covered some of the achievements made in the field of soil mechanics in U.S.S.R., especially on the relation between pore pressure and rate of creep, properties of compressible soils and their behaviour under loads, theory of foundation of finite thickness, design of foundation beds when the foundation bed develops simultaneously plastic and elastic regions and stabilisation of soils carbamide resin.

Some useful points were raised during the lively discussions that followed. It was pointed out that in earth dams, where due to mechanized rolling the compaction would be thorough and failure of downstream slope due to sloughing will follow eventually as a result of continuous downpour, it would be hazardous not to provide an impervious blanket.

There was a good deal of discussion on the practice of adoption either over or lower optimum Moisture content for proper compaction effort. There were two schools of thought. One school advocated the higher value and the other a lower value. It was expressed that since the construction pore pressures depended on zoning and finally on flow nets, it would be of much advantage to place expansive clays at more than O.M.C., which incidentally brings down swelling pressures. It was also pointed out that the compacted value of swelling pressures in the laboratory on the type of proving ring used as higher swelling pressures have been observed with heavier proving rings. However, it was pointed out by one of the speakers that higher compacting effort would increase the dry density, thereby decreasing O.M.C., which therefore was a function of flocculated or dispersed condition of clay and therefore the fixation of the particular value of O.M.C., depended on the nature of structure requiring different compaction effort, whether it was for a road surface or earth dam or some other structures. Regarding the use of upstream membrane, limitations were pointed out that there should be availability of material for the membrane as well as the matching filter and at the same time careful analysis was needed as to the possibility of piping if at a later stage the dam is proposed to be raised.

It was also impressed that in estimating seepage losses from laboratory experiments care should be exercised to compare and preferably to arrive at the losses from field tests only.

An interesting talk was delivered by Monseiur Armond Mayer, Vice-President for Europe region, on the grouting operations adopted on SERRE—POWCON Dam and Rhine Valley Scheme foundation treatment. Explaining the operations he brought out the importance of the selection of grout mix after field permeability tests in the grout holes at different depths. He added that the cement grout would not be effective, since it could be used only in horizontal layers whereby water tightness will not be ensured. Also he cautioned against the existence of contact zones in between alluvial and rock formation and special care was advocated for proper treatment.

He also showed a film on the stabilization technique adopted in one of the recent tunnel excavation in France in very loose soil,—the estabilization being done from chemical injection first and followed up with cement grout to form a stabilized bulb. After that the excavation has been arranged.

RESOLUTIONS

The Conference concluded its session with the adoption of the following resolutions, intended to help development of the knowledge in the field of soil mechanics and foundation engineering in the Asian Region :

(1) That the International Society of Soil

Mechanics and Foundation Engineering may arrange through the good offices of the United Nations for establishing co-ordinating centre in the region which should help promotion of scientific knowledge in the field of Soil Mechanics and Founlation Engineering including growth and establishment of research and teaching centres.

(2) That various National Societies may seek establishing of permanent institutes showing soil samples and analysis, serving as repository of investigation data, observations and behaviour of soil structures in different parts of the region along with well equipped Libraries and Information Centres.

(3) That the National Committees in the region may keep each other informed of the difficult and intricate problems in the subject and be enabled to offer facilities for visits of the engineers and scientists engaged in the field of soil engineering in the other countries of the region.

(4) That in the construction of earth embankments emphasis should be laid on evolving more rapid and economical procedure for quality control of placement and compaction.

(5) That, for development of economic earth structures, it is necessary to install necessary instruments to make observations both during construction and after and use the data for improvements in design.

(6) That any unusual behaviour of earth structures be promptly reported upon in the interests of development of soil engineering.

(7) The special soil stabilization techniques based on the movement of electro-chemicals as reported from Japan, of resins as is being used in U.S.S.R., with low cement content as used in India and with lime as done in Israel may be further persued and reported at the next Regional Conference.

The session concluded with a resolution moved by foreign delegates expressing their appreciation of the work done by the Indian National Committee and a vote of thanks by the Organizing Secretary.

[*Continued from page 18*

Soil Mechanics and Foundation Engineering

Millions of our people ply their vehicles on tracks, which are nothing but soil. Considerable amount of work is therefore, required to be done to stablise the ordinary soil roads, so as to reduce disintegration and pulverisation of soil surfaces under stresses of loads and vagaries of weather. Proper compaction, admixture of easily procurable ingredients and proper maintenance have enabled some stabilised earthen roads to stand the test of time and actual field usage. These studies open up a vast field for improvement of our village communication lines. Stabilisation of slopes of embankments subjected to erosion, construction of dams and even katcha houses can be greatly improved, if specialised studies made in these fields are judiciously applied by the builders. Engineering studies of soils and mechanics thereabout therefore, go a longway in economising our construction and mainetnance cost and expediting the pace of our developmental activities on various fronts.

Soil studies, however, are not simple, because soil is not a manufactured product like iron and steel. In its study numberless variables have to be faced. Besides, its properties change from place to place and from situation to situation. Superimposed conditions also alter its behaviour and reaction. At the same time, it is almost impossible to reproduce in the laboratory natural processes of consolidation, which take hundreds and thousands of years to accomplish under natural conditions. The science of Soil Mechanics therefore, is far from perfection. Besides, a close probe is often required intto underlying strata. Unlike the medical man, to whom X-ray is an easy aid for probing into human body, a soil scientist and engineer has to depend mostly on boring and geological observations. They do indicate the nature of strata. But great skill is involved in predicting stability and strengtth of underground strata with adequate precision. Mathematical analysis does afford a guide. A systematised study and pooled experience alone can lead to stable policies and practices, which could be followed in resolving difficulties generally faced by engineers in the field of soil stabilisation and foundation engineering. There are many problems in this basic engineering science still awaiting solution. Collaboration among workers of different countries help crystalising ideas in respect of many baffling problems and giving shape to universally accepted principles applicable to regions situated in different parts of the world. Afterall, all soils are part and parcel of our global crust and they all rest on the common core of this planet.

Irrigation Policy : III : Priorities for Irrigation

By C. S. PARTHASARATHY

It is now generally recognised in our country that the success of a Plan is dependent, in a large measure, upon the success in the matter of agricultural production. Production of more foodgrans to meet these requirements thus assumes paramount importance. Successful agriculture in most parts of the country is not possible without the use of water. The enormous land resources of India cannot be put to productive use without a simultaneous and parallel development and use of our vast water resources. In fact, an integrated development of land and water resources is of fundamental importance to the economy of our country. Irrigation, be it major, medium or minor, is one of the principal requirements for agricultural expansion. Its utility is becoming even more important with the increasing use of fertilisers and other improved practices in agriculture.

Situated as India is geographically, with a tropical or sub-tropical climate and with practically no rainfall over a large part of the year and uncertain rains during the monsoon months, successfully cultivation or growth of crops is not possible in many parts of the country without the aid of irrigation facilities. In the absence of irrigation facilities, large areas produce only a catch crop depending on rainfall alone, which is often deficient and unevenly distributed, from the point of view of agricultural requirements, particularly during the critical period of growth of crops. It is not surprising, therefore, that the average yield per acre of cultivated area is very low. With the provision of irrigation facilities, the yield per acre can be increased considerably. In some areas, this increase may be of the order of 50% but in areas of low and uncertain rainfall, this increase may be 2 to 5 times the yield from unirrigated lands. Also, large areas of cultivable land, now barren and lying waste, can be cultivated and put to productive use, if irrigation facilities are provided. The quantity of water and the frequency of irrigation required to mature crops vary in different parts of the country. In some areas, like parts of Rajasthan, nothing can be grown without the artificial application of water. In some areas, irrigation works are required, as a stand-by, to be used once probably in two or three years during a drought and, at others, for some of the more valuable crops or only in the period just before the rains set in. There are large tracts, however, particularly in Rajasthan, Punjab, Western U.P., and parts of the Deccan, where irrigation is necessary for cultivation and is required almost all the year round.

Some salient features in regard to land utilisation and status of irrigation in the country, as obtaining in 1955-56 (end of the First Plan period), are given below :—

	Million acres (approximate)
(*i*) Gross area	806
(*ii*) Classified or reporting area	720
(*iii*) Forests	125
(*iv*) Not available for cultivation	118
(*v*) Uncultivated land excluding fallows	97
(*vi*) Current fallows	29
(*vii*) Fallows other than current fallows	31
(*viii*) Culturable area	475
(*ix*) Cultivated area	347
(*x*) Net area sown	318
(*xi*) Net irrigated area	56
(*xii*) Gross irrigated area	64

At the beginning of the First Five Year Plan (i.e. 1951-52), the total irrigated area in the country was of the order of 50 million acres. Nearly 80% of cultivated land was still without irrigation then. Assessment of the country's water resources revealed, on the other hand, that there was ample potential for further exploitation ; hardly 10% of the total water resources, in terms of annual flow in all the river basins, was utilised by the end of the First Plan (i.e. 1955-56). Thus, in order to meet the country's requirements in food and improve its economic status otherwise, one of the foremost questions before the planners has been : how to bring about a rapid development of the country's irrigation resources in a short period ?

Irrigation, whether by canal or lift irrigation, has

also the additional advantage of enabling the cultivator to sow his crop at the right time and thereby get increased out-turn. As an illustration, cotton under barani conditions in Punjab can be sown with the advent of monsoon rains, i.e. beginning of July and it is actually being sown in barani areas in July, but the yield of cotton rises enormously—sometimes even 100 to 200 per cent higher, if it can be sown at the end of April or May, and this is possible only if irrigation supplies are available. Irrigation also enables the cultivator to grow green manure crops at a suitable point of time in a year, without having to forego a normal crop. This is extremely important in view of the fact that fertility of the soils in India is generally at a very low ebb and this is one of the prime factors for low yield of crops in our country. Benefits in irrigation may not be comparable in all areas. While in areas of moderate or even good rainfall, increase in yield may be only of the order of $\frac{1}{3}$rd of a ton per acre or even less, irrigation in areas with scanty and precarious rainfall makes a world of difference and prevents total famine conditions. For instance, in areas like Hissar district in the Punjab or Rajputana, irrigation means not $\frac{1}{3}$rd of a ton but even a ton per acre, as the soils in such areas are usually fertile and in the absence of monsoon rains, they usually experience famine conditions, so that irrigation in areas of moderate or abundant rainfall does not confer the same benefitts, as it does in areas of scanty rainfall.

There is also another aspect. Irrigation and fertilisers are two complementary factors, in as much as fertilisers can give best results only if there is adequate moisture present in the soil; otherwise, it can do more harm than good. Likewise, irrigation can give optimum results in the form of increased production only if the fertility of the soil is maintained at a high level either by the application of artificial fertilisers or better still, by the addition of organic matter, either in the form of farm-yard manure or green manure crops.

The following table sets out broadly the relative size of the major and medium; and the minor irrigation programmes under the First and Second Plans :

	Major & Medium Irrigation	*Minor Irrigation*
I Plan		
(*i*) Total estimated costs of schemes (Rs. crores)	750	90
(*ii*) I Plan provision (Rs. crores)	340	90
(*iii*) Actual expenditure (Rs. crores)	300	75
(*iv*) Total designed irrigation benefits on full development (M. acres)	22	11.2
(*v*) Target for the end of I Plan (M. acres)	8.5*	11.2
II Plan		
(*vi*) Total estimated cost of new schemes (Rs. crores)	500	120
(*vii*) Plan provision (Rs. crores)	400	120
(*viii*) Total designed irrigation potential on full development of new schemes (M. acres)	16	9
(*ix*) Original/Revised target by end of Second Plan (M. acres)	12/10	9/9

(*Note* :—(a) * This included some minor irrigation & tube-well schemes.
(b) The figures given above are approximate.)

There is no doubt that for maximum integrated development of irrigation resources, implementation of works belonging to the above categories is equally important. In the selection of irrigation schemes, there continues to be need for a careful balance between major and medium irrigation schemes on the one hand and minor works on the other. Each area has to be served by the kind of schemes for which it is best suited. These schemes are, therefore, complementary in character and scope. In fact, there are certain tracts where major and medium schemes may be considered more feasible and others which can be developed only through minor irrigation schemes. There is yet a third category of areas where only co-ordinated programme of minor, medium and major irrigation schemes can provide the desired optimum utilisation of the available land and water resources.

A few words about the relative advantages of major and minor irrigation works. Major irrigation schemes utilise surplus waters which would otherwise run to waste. They benefit large and extensive areas, give more assured protection in years of scarcity and also can often be designed to serve a multiplicity of purposes. Minor irrigation works can be executed in a relatively short period and with small initial outlay. They yield quicker results, depend on local resources and there may be no need for obtaining foreign machinery and equipment. This may be of some significance in the present context of the tight foreign exchange position. However, the protection afforded by minor

[*Continued on page 32*

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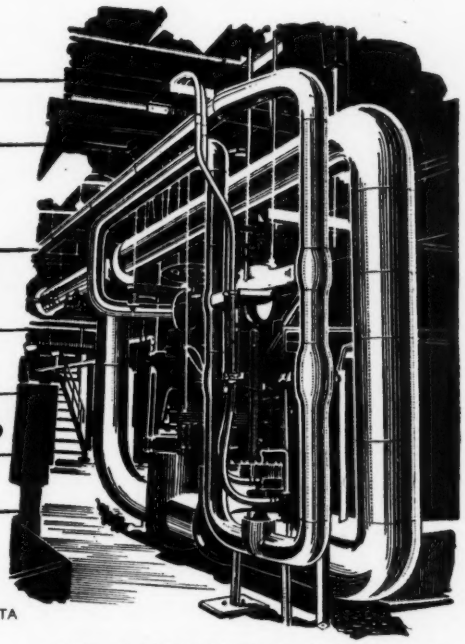

Feed pipework at the boiler feed pumps at Trombay Thermal Power Station

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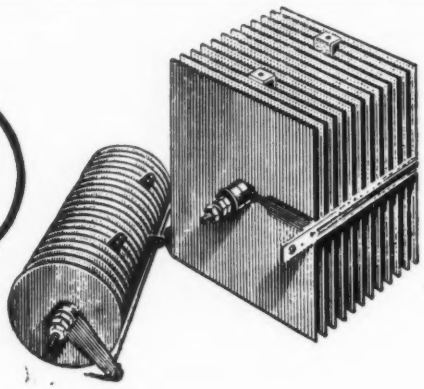

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Organic Moderated and Cooled Reactors

By L. W. BOXER

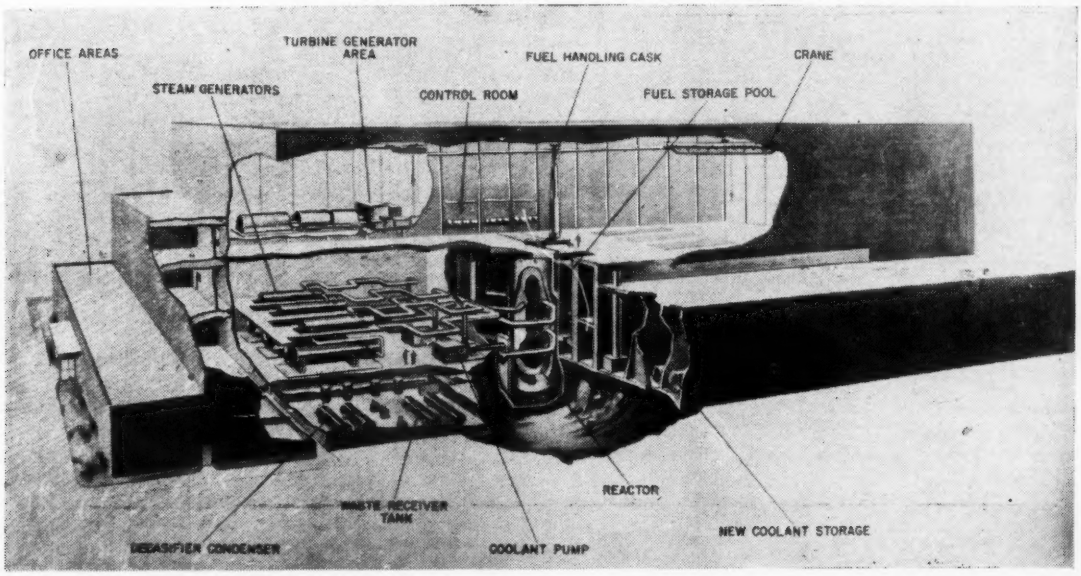
In May 1959 The English Electric Company entered into a licence agreement with Atomics International Division of North American Aviation for the exchange of information on the technology of the organic reactor system. Atomics International are the world's leading experts in this type of reactor, in the development of which they continue to receive strong support from the United States Atomic Energy Commission.

The system is very simple and essentially comprises a mild-steel vessel containing a lattice of uranium fuel rods slitable clad, and through which an organic hydrocarbon compound is pumped. The heat generated by nuclear fission in the fuel rods is thus removed by the organic coolant, which is then passed through a simple shell and tube heat exchanger to produce steam. The organic material is finally pumped back to the reactor vessel for further heating in the core. A cut-away view of a typical reactor plant is shown in Fig. 1.

DUAL FUNCTION OF THE ORGANIC MODERATOR

During its passage through the reactor the organic compound acts not only as a coolant but also as a moderator, and slows down the fast neutrons produced during nuclear fission to energy levels at which further fission reactions are most likely to occur. The moderating properties of the hydrocarbon are due to the fact that hydrogen can slow down a fast neutron in only a few collisions (i.e. about 18 on average) compared with the large number of collisions necessary in graphite (about 115 on average). This is due to the fact that the hydrogen atom, being one-twelfth the weight of the carbon atom and only very slightly heavier than a neutron, is able to absorb more energy from the neutron at each collision. However, some neutrons are lost by being captured in the hydrogen atoms and in undergoing conversion to deuterons (heavy hydrogen atoms). This means that, although a hydrogen moderated system is more compact than a graphite system, some enrichment of the fuel is necessary to compensate for loss in the moderator. The problem of neutron capture can be overmome by using heavy water (D_2O) but this is very expensive, and in any case the average total distance travelled

Fig. 1: Cutaway View of typical O.M.R. Power Plant



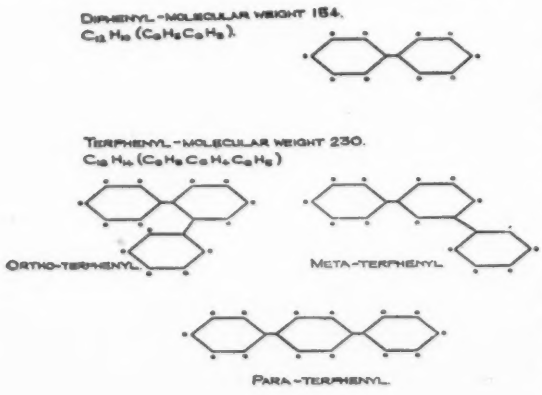
by a neutron during its lifetime in a D_2O reactor is of the same order as in graphite, so the system would be almost as bulky. A further disadvantage of using water as a moderator is that oxygen tends to react with fast neutrons, giving rise to an undesirable degree of radioactivity.

An alternative therefore is a hydrocarbon moderator containing the highest possible amount of hydrogen, since it is the latter element which is responsible for nearly all the moderating properties of the compound, the carbon in the molecule having a very small effect as a moderator and merely acting as a carrier for the hydrogen. The system still requires enriched fuel owing to the wasteful capture of neutrons by the hydrogen atoms.

In order to examine the feasibility of this reactor concept, an Organic Moderated Reactor Experiment was constructed for the U.S. Atomic Energy Commission at the National Reactor Testing Station in Idaho, and has now been operating successfully up to a maximum of 12 MW thermal power for over two years. The experiment has yielded valuable data on the behaviour of certain organic compounds under irradiation, and this operating experience has revealed the principal disadvantage of the system, namely that irradiation of the organic compound has the effect of producing heavy polymers or long-chain molecules which tend to have a detrimental effect upon the heat-transfer properties of the coolant. It is therefore necessary to remove these high-boiling-point residues continuously and to make up with fresh coolant. The decomposition rate observed in the O.M.R.E. indicates that coolant make-up rates in a power reactor of the order of 1 lb. per thermal MWh may be expected.

The organic compounds employed are polyphenyls (homologues of benzene, C_6H_6), their molecular structures being indicated in Fig. 2.

Fig. 2: Chemical Structure of Reactor Polyphenyls



The commercial compound in current use is Santowax R, a mixture of diphenyls and terphenyls, and which is a soft waxy substance at room temperature. It is necessary therefore to pre-heat the reactor and primary coolant loop above the melting point of the organic moderator/coolant when the system is not operating at nuclear power.

The very considerable advantages of the organic moderated reactor can be summarised as follows :—

1. The use of a hydrocarbon material as a combined moderator and coolant reduces the size of the core very considerably, owing to the superior moderating property of hydrogen atoms. There is thus a corresponding reduction in capital cost.

2. The low vapour pressure of the coolant means that only low operating pressures are needed for a heat cycle in which reasonable steam conditions are obtained. This means that there are no pressure problems as with water moderated and cooled reactors.

3. The compound is chemically compatible with cheap materials (e.g. carbon steel, aluminium), and its reaction rate with uranium is also very slow.

4. The degree of radioactivity imparted to the coolant is very low, which means that not only is there a considerable saving in shielding materials, but it is also possible to do a limited amount of maintenance work on a shut-down coolant loop with the reactor operating at reduced power.

5. Low operating pressures and low radioactivity levels eliminate the need for expensive containment structures.

CAPITAL COSTS AND GENERATING COSTS

In view of the economies introduced by the features listed above, it is possible to construct O.M.R. nuclear power stations by established conventional engineering techniques, with standard items of equipment and low-cost materials. However, the comparatively late start of the engineering of organic moderated reactors compared with other reactor system has resulted in a good deal of conservatism being inherent in current designs. For the time being therefore the overall simplicity and economy of the organic moderated reactor is not entirely reflected in the present costs per kW of net electrical output. Nevertheless, considerable potential increases in output are present in a given size of plant, and are almost certain to be realised when operating experience has enabled relaxations to be

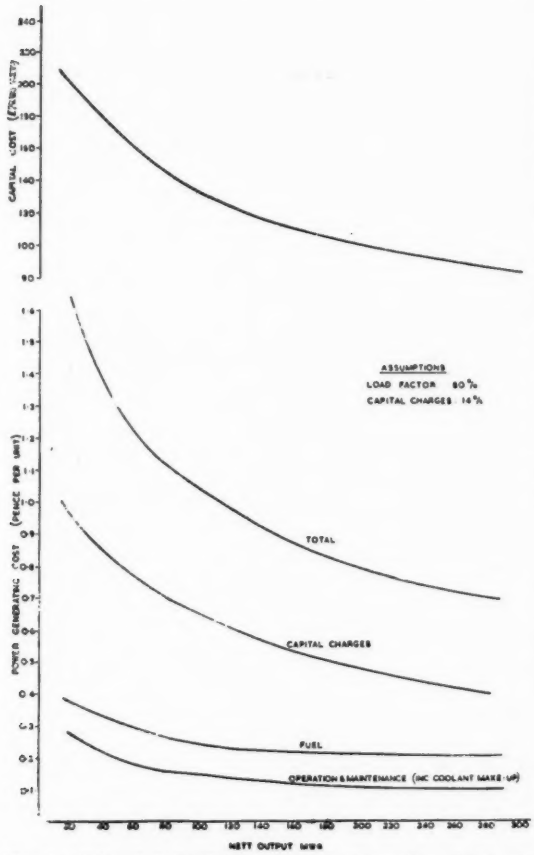


Fig. 3: Estimated Capital Costs and Generating Costs of O.M.R. Nuclear Power Station (Based on U.S. Materials and Labeur).

made in the design margins on heat transfer calculations, fuel element temperatures and burnups, in addition to anticipated economies in organic make-up costs and fuel element fabrication costs.

The curves in Fig. 3 provide a summary of the present estimated capital costs and generating costs of O.M.R. nuclear power stations with construction based on materials and labour rates in the United States.

PRESENT PROGRESS IN O.M.R. PROJECTS

An O.M.R. plant is now being constructed by Atomics International at Piqua, Ohio, under contract to the United States Atomic Energy Commission, and when completed late in 1961 the plant will supply steam to the existing municipal power station, thus providing a supplementary source of power equivalent to 11.4 MW electrical output.

The Atomic Energy Commission is also sponsoring the design of an experimental organic cooled reactor for installation at the National Reactor Testing Station in Idaho. This plant also is planned for completion late in 1961 and will provide facilities for advanced development work on such features as irradiation characteristics of organic compounds, fuel-element performance and core physics. Engineering work will be carried out by the Fluor Corporation, with Atomics International as sub-contractors for the nuclear portion of the plant and its auxiliaries.

A further A.E.C. project will be the construction of a complete prototype O.M.R. nuclear power station in excess of 50 MW electrical output. American electrical utilities are being invited to submit suitable proposals to the A.E.C. during the next few months.

Interatom, the associated company of Atomics International in Germany, is at present engaged upon a study for a nuclear ship of 10,000 shaft-horse-power and up to 40,000 tons deadweight. This study is being carried out on behalf of a group of German shipbuilding firms with the support of the German Government, and valuable information is being accumulated on the specialised application of organic reactors to marine propulsion.

Finally, the British Ministry of Transport has recently called for tenders for a 20,000 s.h.p. nuclear propulsion unit incorporating either a boiling-water reactor or an organic moderated and cooled reactor equipment for a 65,000 tons deadweight tanker. The English Electric Company will be putting forward a proposal for a nuclear propulsion unit based upon the organic moderated reactor.

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Trends of Coal and Electrical Energy Purchases by India Manufacturers

By D. C. DATTA

Coal and electrical energy are pre-requisites for the industrial development. Coal as a source of steam power and heat, and electric power from steam, waterflow or oil are essential in any large scale manufacturing process. With the growth of industries, coal as a source of steam power for utilisation in the manufacturing process is gradually being replaced by electrical energy. Increase in productivity is dependent to a large degree on a more intensive and extensive use of electric power in industry. Increase in use of electrical energy in industry reflects the technological advance as electricity, the most versatile form of energy is indispensable for bringing out industrial development through rapid mechanisation. In India, steam is the major source of electric power. 53 per cent of the total electrical energy generated from public utility concerns is obtained from steam. The remaining 47 per cent is shared between hydraulic and oil in the ratio 19 : 1. The quantity of coal consumed in the generation of electricity by public utility concerns is 40 lakh tons which constitutes about 10 per cent of the coal extracted from the mines. In an underdeveloped country like India where the resources of oil and high grade metallurgical coal are comparatively limited, the development of electric generation industry should generally be based on the steam power from low grade coal and the transformation of hydraulic energy. Keeping in view the higher capital cost of the hydel power stations and the need of balanced utilisation of this important natural resource namely coal the electric generation industry should mainly be developed from the steam power from coal of relatively low thermal value. The probable reserves of coal including deposits of brown coal, peat etc. is nearly 62,636 million metric tons out of which about 3 per cent is good quality coking coal. In the national interest it is essential to conserve this high grade fuel for metallurgical and other important purposes.

TRENDS OF COAL AND ELECTRICITY PURCHASES

In the light of above observations, it is interesting to study the trends of coal and electrical energy purchases by the twentynine groups of power consuming manufacturing industries of India each factory of which employs 20 workers or more. Though the coverage is limited, in view of high contribution from this group of industries in the total product of the power consuming industrial sector of the national economy, the data on coal and electrical energy purchases from this group can be considered to be representative of the power consuming industrial sector. The following Table shows the percentage distribution of total purchase value of fuel, electricity, lubricants and water by three major namely coal, electricity and others in the twentynine groups of power consuming manufacturing industries of India in each of the period 1946-57.

TABLE 1

PERCENTAGE DISTRIBUTION OF TOTAL PURCHASE VALUE OF FUEL, ELECTRICITY, LUBRICANTS AND WATER BY THREE MAJOR GROUPS NAMELY COAL, ELECTRICITY AND OTHERS IN TWENTYNINE GROUPS OF POWER CONSUMING MANUFACTURING INDUSTRIES IN EACH YEAR OF THE PERIOD 1946-57.

	purchase value (in %) of			
Year	*coal*	*electricity*	*other*	*total*
1946	55.3	18.7	26.0	100.0
1947	56.2	17.3	26.5	100.0
1948	53.9	17.7	28.4	100.0
1949	53.4	20.5	26.1	100.0
1950	52.5	20.3	27.2	100.0
1951	49.9	21.5	28.6	100.0
1952	48.5	21.4	30.1	100.0
1953	47.4	24.1	28.5	100.0
1954	45.1	27.8	27.1	100.0
1955	42.5	29.1	28.4	100.0
1956	42.3	29.6	28.1	100.0
1957	44.4	28.5	27.1	100.0

The percentage share of purchase value of coal has come down from 55.3 in 1946 to 44.4 in 1957; on the other hand that of electricity has gone up by nearly 10 per cent during the corresponding period. Comparatively the share of the group 'others' has remained more or less steady. Thus the share in the purchase value of coal is gradually

being replaced by that of electricity. It may be stated that the industrialists are more and more depending on electricity as source of power relative to coal.

The extent of replacement in the purchase values in different industries is not uniform. In fact it will depend on the consumption patterns of coal and electricity in individual industries and technical factors in the establishments operating upon their relative demand. To what extent the purchase value of coal is substituted by that of electricity in each of the six selected manufacturing industries namely cement, cotton textiles, jute textiles, aluminium, copper and brass, iron and steel and general engineering and electrical engineering are reflected in the following Table.

TABLE II

PERCENTAGE VALUES OF COAL AND ELECTRICITY IN THE TOTAL PURCHASE VALUE OF FUEL, ELECTRICITY, LUBRICANTS AND WATER IN THE SIX SELECTED INDUSTRIES OF INDIA FOR 1946 AND 1957.

Industry	*percentage value of*			
	coal		*electricity*	
	1946	*1957*	*1946*	*1957*
1. cement	83.6	82.0	13.6	14.7
2. cotton textiles	46.2	30.9	27.2	42.9
3. jute textiles	52.5	34.7	29.9	54.4
4. alluminium, copper and brass	32.7	18.8	12.9	38.4
5. iron and steel	85.8	61.0	5.2	12.8
6. general engineering and electrical engineering	18.0	8.9	24.4	30.0

After the lapse of nine years, the replacement of purchase value of coal by that of electricity is found to be most pronounced in the alluminium, copper and brass industry group. The percentage for coal has come down by a about 14 per cent and that of electricity has gone up by nearly 25 per cent. It may be mentioned that alluminium industry is the most power intensive—production of 1 kg of aluminium requires on an average 22 kwh of electrical energy. The percentages of purchase value of coal have dropped from 85.8 and 46.2 to 61.0 and 30.9 respectively in iron and steel and cotton textile industries. Corresponding rise in the percentage value of electricity is 16 per cent in case of cotton textile but only 8 per cent in case of iron and steel industry. A major proportion of the drop in the percentage of coal purchase value in iron and steel industry is accounted for by the rise in the percentage value for the group 'others'. However, though in percentage terms, the extents of replacement are different for different industries, in general the increase in the percentage of purchase value of electricity is marked and in this respect all the six industries fall into the same category. This is not only true for these selected industries but in general also for all power consuming manufacturing industries. This shows up that there is the increasing tendency to purchase electrical energy directly by the industrialists.

EFFECT OF PRICE VARIATION

Uptil now, this discussion is limited to value figures which are obviously influenced by the trends of the prices of coal and electricity and thus by the change in the structural relationship of their prices. Tariff for bulk supply of electrical energy is in general determined by the voltage at supply, quantum of energy consumed, maximum demand and the change in fuel cost of the generating agency. The average purchase value of a unit of electrical energy has gone up from 3.53 nP in 1946 to 5.07 nP in 1957, taking all the twenty-nine groups of power consuming manufacturing industries together. Corresponding rise in the average price per ton of coal normally inclesive of transport charges is from Rs. 21.25 in 1946 to Rs. 33.26 in 1957. Thus whereas the average price of electricity has registered a rise of 44 per cent that of coal, 57 per cent. On the other hand the percentage of coal purchase value has dropped by 10.9 per cent and that of electricity purchase value has gone up by nearly 10 per cent.

COMPARISON IN PHYSICAL TERMS

The trends of coal and electricity purchases in physical terms by the twenty-nine groups of power consuming manufacturing industries will also throw light on the change in their pattern of demand for the manufacturing process. In this the influence of price factor is eliminated and the data is presented more objectively. The following Table shows the indices of coal and electricity purchases by the twentynine groups of power consuming manufacturing industries.

TABLE III

INDICES OF COAL AND ELECTRICITY PURCHASED BY TWENTY-NINE GROUPS OF POWER CONSUMING MANUFACTURING INDUSTRIES FOR EACH YEAR OF THE PERIOD 1947-57.

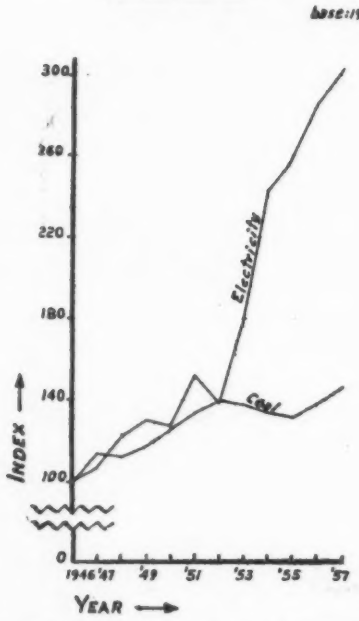
base : 1946=100

year	*index of*	
	coal	*electricity*
1947	112.9	107.6
1948	112.5	122.7
1949	116.9	130.2
1950	126.6	127.4
1951	134.0	152.3
1952	140.2	139.7
1953	138.0	176.6
1954	134.2	242.4

1955	132.7	258.8
1956	138.4	285.5
1957	146.4	303.0

During the period 1946-57 the coal purchase index has gone up by 46.4 point against the rise by 203 points by the electricity purchase index. The overall average annual rate of increase is 4.2 points in case of coal whereas in case of electricity it is as high as 18.5 points. These indices are also represented in Graph (A).

GRAPH (A): INDICES OF COAL AND ELECTRICITY PURCHASES FOR EACH YEAR OF THE PERIOD 1947-'57



The indices of coal and electricity purchases for the six selected industries for 1957 with base 1946 are shown in Table IV.

TABLE IV

INDICES OF COAL AND ELECTRICITY PURCHASES IN THE SIX SELECTED INDUSTRIES FOR 1957.

base : 1946=100

industry	*index of coal*	*index of electricity*
1. cement	537.8	772.8
2. cotton textiles	119.8	214.7
3. jute textiles	69.9	208.1
4. aluminium, copper and brass	109.9	232.0
5. iron and steel	92.2	480.5
6. general engineering and electrical engineering	127.7	409.2

The index of electricity purchase for any industry of the six selected for 1957 is higher than the corresponding index of coal purchase. In each of these selected industries purchase of electricity is increasing on an average at a faster rate than that of coal and they being complimentary to each other from the viewpoint of energy requirement coal purchase is gradually being replaced by electricity purchase. The replacements are more pronounced in iron and steel and in general engineering and electrical engineering industries. It is significant to not that in each of the industries, iron and steel and jute textiles, the index of coal purchase is less than 100.

PURCHASE PER WORKER

Of all the factors which affect the growth of industries, the use of energy is the most important. The question of efficiency in the production process is linked up with the quantum of energy used per operative. Production trends of industries will be associated with the coal and electricity purchase per worker. For the twentynine groups of power consuming manufacturing industries each establishment of which employs twenty workers or more, the trends of coal and electricity purchases per workers and the general trend of industrial production in India are shown in the Table below.

TABLE V

TRENDS OF COAL AND ELECTRICITY PURCHASES PER WORKER IN POWER CONSUMING MANUFACTURING INDUSTRIES AND OF INDUSTRIAL PRODUCTION IN INDIA.

base : 1951=100

year	*index of purchase per worker: coal*	*index of purchase per worker: electricity*	*index of production industrial*
1952	103.8	90.8	103.6
1953	104.0	116.9	105.6
1954	96.5	153.2	112.7
1955	92.1	157.8	112.4
1956	91.0	164.8	132.6
1957	100.6	182.7	137.3

It will be seen that with the rise in industrial production, the electricity purchase index has in general increased. Since 1953, both the index of industrial production and that of electricity purchase per worker have gone up. On the other hand this is not true in case of coal. The production trend in the industrial sector has obviously been influenced by the total energy requirement and that relatively the share of coal purchase in the total energy has decreased is reflected by the downward

trend during the period from 1953 to 1956. From 1956 both for coal and electricity purchases, the trend is upward but the rise in electricity purchase is more marked. This result is significant from the viewpoint of productivity per worker. For increasing the productivity per worker, the purchase of electricity will be preferable as the additional employment necessitated for the conversion of coal to utilisable form of energy can be avoided. In a free economy, legislation or other impositions not withstanding, there will be tendency to shift the balance towards the purchase of electricity.

COMPARISON FROM THE PRODUCTIVITY ANGLE

An objective appraisal of the merit of electricity purchase from the productivity viewpoint can be obtained when the data on physical production of a single industry is related to the corresponding data on purchase of electrical energy. The cement industry has been considered for this study from the productivity angle. In certain ways the cement industry is ideal for the purpose. The output in the period reviewed was homogeneous and there are only minor variations in quality. Unlike the other industries there was no product-mix problem. These advantages have eliminated the question of weighting different products from an industry on the basis of power requirement in the manufacturing process. Before taking up the consideration of this problem from productivity angle it will be advantageous to observe the change in the integration of coal and electricity purchases per ton of output during the two periods 1946-48 and 1955-57.

TABLE VI

PURCHASE OF COAL ELECTRICITY PER TON OF CEMENT OUTPUT DURING THE TWO PERIODS 1946-48 AND 1955-57.

		purchase of		*purchase p. ton of output*	
period	*output* (*lakh ton*)	*coal* (*lakh ton*)	*electricity* (*lake kwh*)	*coal* (*ton*)	*eletricity* (*kwh*)
1946-48	28.63	12.08	972.16	0.42	33.97
1955-57	139.43	47.70	6320.20	0.34	45.33
increase	110.80	35.62	5348.04	0.32	48.27

There is marked decrease in coal purchase and increase in electrical energy purchase per ton of cement output in 1955-57 over that in 1946-48. For the increased output the increase in electricity purchase per ton of output is most significant. Thus with the increase in production the electricity purchase per ton of cement output is higher.

The trends of productivity per worker and electricity purchase by the cement industry have been shown in the Table below. The productivity will be closely related to the energy consumption and thus also to the electricity purchase. This fact has been brought out from Table VII.

TABLE VII

ELECTRICITY PURCHASES AND INDICES OF PRODUCTIVITY PER WORKER FOR EACH YEAR OF THE PERIOD 1947-57 IN CEMENT INDUSTRY

Year	*electricity purchase* (*crore kwh*)	*Productivity per worker* (*base*: 1946=100)
1946	3.30	100.0
1947	3.03	90.8
1948	3.39	98.5
1949	5.08	119.2
1950	7.22	159.2
1951	10.90	171.3
1952	12.18	224.9
1953	12.20	243.7
1954	15.71	278.2
1955	16.68	280.5
1956	21.04	227.2
1957	25.48	259.4

The rise and fall of the quantum of electricity purchased for the manufacture of cement are generally accompanied respectively with the rise and fall of the productivity index. There are various factors which influence the labour productivity, the use of electrical energy being one of them. The two series also show high corelation, the co-efficient of corelation being 0.87. This industry is not electric power intensive ; still the influence of electric power purchase on the productivity is very prominent.

CONCLUSION

The purchase of electric power wherever it can replace coal purchase for the production of commodities has important bearing on the industrial economy. The industrialists need not have to divert their energy and resources for power production requiring employment of additional capital and labour and thus can concentrate on commodity production. Power needs of the factories can be supplied from large scale power generating units. Thus harnessing the resources for the generation of electricity through large scale power stations for catering industrial needs seems to be one of the basic considerations for achieving higher production in the industrial sector.

[*Continued from page 24*

Irrigation Policy: III: Priorities For Irrigation

schemes may be substantially cut short in drought years when protection is most needed. The tanks, in particular, may fail to store water when there is failure of rainfall in the locality. Also, maintenance of minor works may be neglected. The G.M.F. Enquiry Committee observed in 1952 that many minor irrigation schemes constantly fell into derelict condition.

It will also be observed from the Table given above that the major and medium irrigation programme has been larger in size, in both the First and Second Plans and is designed to give more assured and dependable additional benefits in irrigation. Considering the more assured benefits, the programme for major and medium schemes should continued to occupy a prominent place in future plans for economic development of our country.

Adequate data are not available for determining the eventual target for irrigation or the total irrigation development possible under different kinds of sources in the country. It has, however, been roughly estimated that about 100 million acres may eventually be irrigated by multi-purpose, large and medium irrigation works. Perhaps, another 100 million acres could be irrigated under other categories of irrigation sources, thus making a total of about 200 million acres under irrigation from all sources. The irrigated area by the end of the Second Plan may be of the order of 80 million acres, leaving a large scope for further development of irrigation in the country.

It is, thus, clear that for incrreasing production of food grains and other agricultural produce for the growing population in the country, it is necessary that as large a number of irrigation projects as possible should be undertaken wherever there are facilities for such projects

In conclusion, it should be made clear that whatever views have been expressed in this paper are the author's own and not those of the Government or organisation in which he serves.

[*Continued from page 15*

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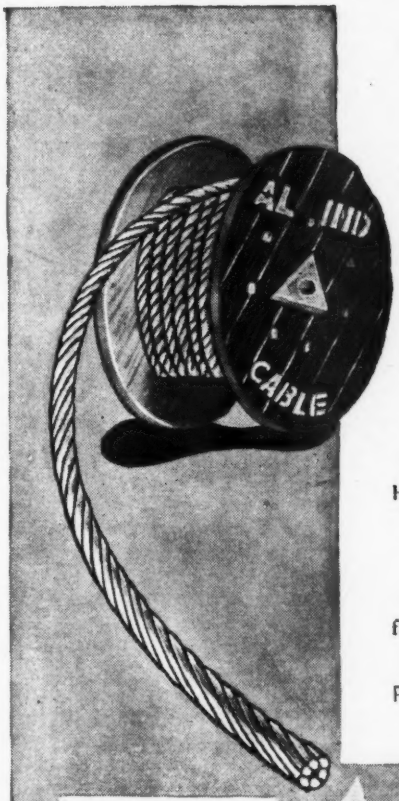

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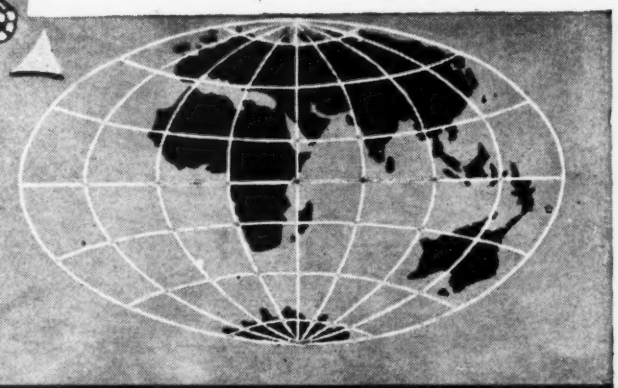

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Contributors include: Mr. Eugene Black, President of the World Bank; Dr. Charles Jaeger, Leading Expert on Hydro-Power Project; General Itschner, Chief of Engineers, U.S. Army; Prof. Salvadori of California University; Dr. E. Nonveiller, Head of Soil Mechanics & Foundation Dvn., Yugoslavia; Gordon R. Clapp, President, Development & Resources Corporation, New York; W. L. Voorduin, Formerly of the TVA (planner of DVC); A. M. Komora, Formerly of the TVA and Ex-Chief Engineer, DVC; Grant Bloodgood, Assistant Commissioner & Chief Engineer,Bureau of Reclamation, U.S.A.; H. Sanford, Bureau of Reclamation, USA; E. S. de Breauvery, Head of the Water Resources Development Centre, United Nations; Prof. Koichi Aki, Tokyo University, Japan; Sir J. Eccles, Dy. Chairman, Electricity Council, U.K; V.T. Krishnamachari, Ex-Dy. Chairman, Planning Commission, Govt. of India; Dr. A. N. Khosla, Member, Planning Commission, Govt. of India; Dr. J. W. Whitaker, Director, Central Mining Research Station, India; Dr. P. S. Lokanathan, Director-General, National Council of Applied Economic Research; Kunwar Sain, Chairman, Rajasthan Canal Project Administration; N. D. Gulhati, Addl. Secretary, Ministry of Irrigation & Power, Government of India; M. Hayath, Chairman, Central Water & Power Commission, Govt. of India; Dr. K. L. Rao, Member, Central Water & Power Commission, Govt. of India; Dr. N. K. Bose, Special Officer, Irrigation & Waterways, Calcutta; D. V. Joglekar, Advisor, Central Water & Power Research Station; M. N. Chakravarty, In-charge, Atomic Power Project, Atomic Energy Commission.

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New Developments in Soviet Power Engineering

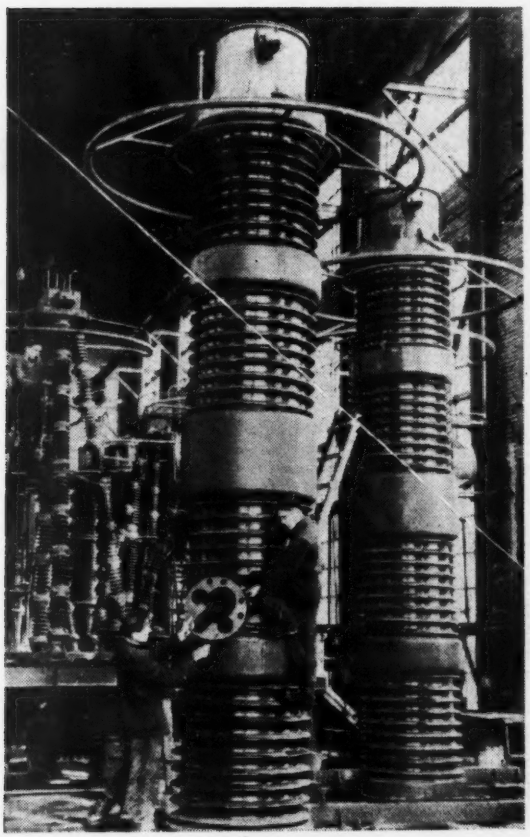
By V. FEDOREV

A total of 100,000 kilometres of power transmission lines were in operation in the Soviet Union by 1959, conveying electricity at over 35 kV. The Seven-Year Plan provides for additional 200,000 kilometres, or twice as much as has been built in the past forty years.

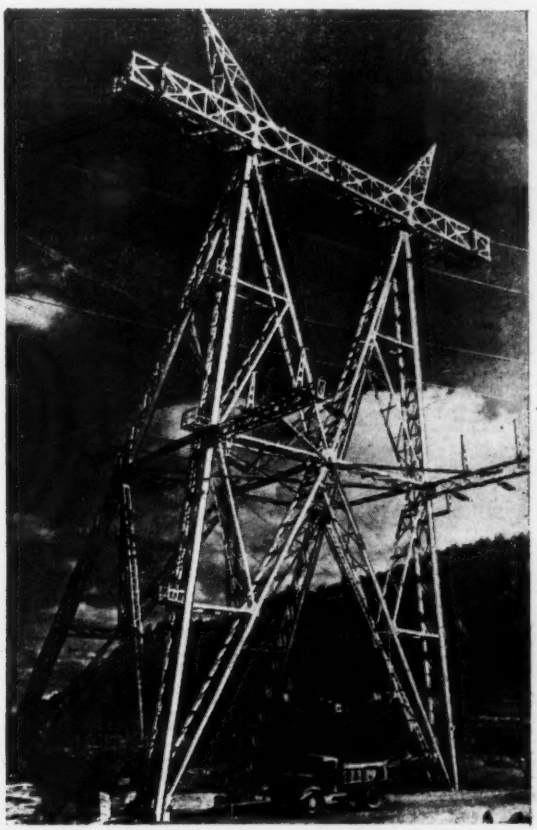
The Soviet state is to spend on it 17,000 million rubles. Some 100 kilometres of transmission lines will be put into operation every day.

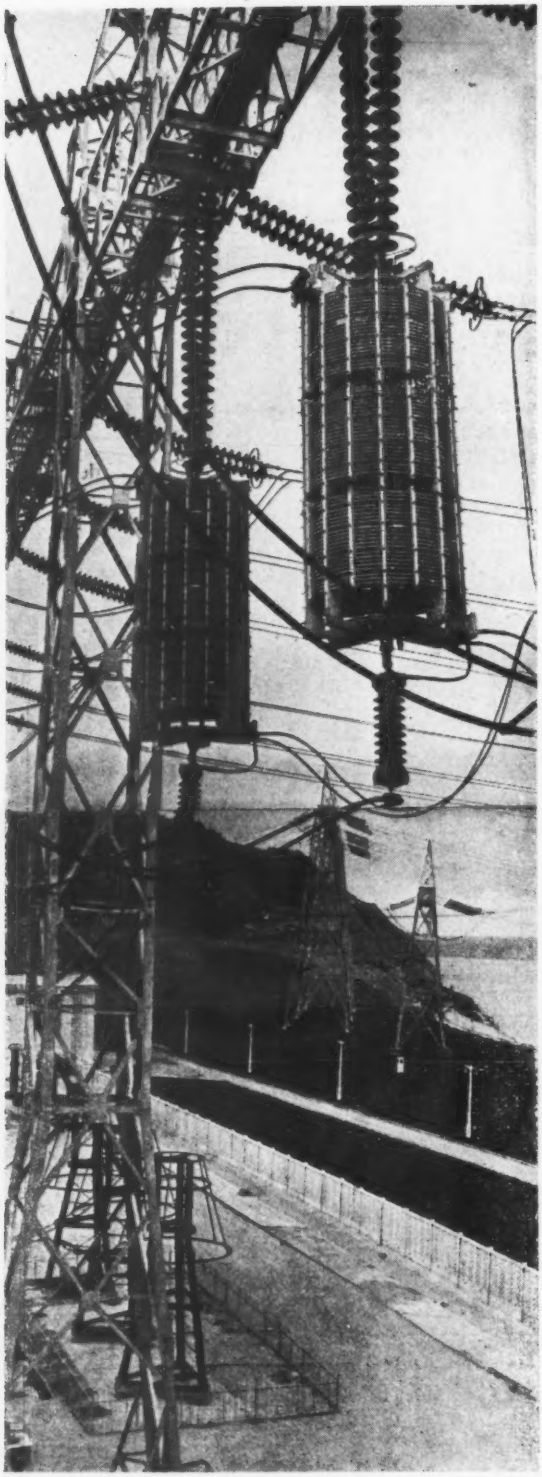
Recently A. Harriman, a prominent US political leader, visited the Soviet Union. At his closing press conference in Moscow he said the Soviet power transmission lines were better equipped than America's. The maximum voltage transmitted in the United States is 350 kv. The Soviet power engineers have built and are successfully operating a 400-kv Volga-Moscow-Urals line running for 2,000 kilometres. Construction work is being com-

Assemblying air switches for sub-stations on the high-voltage line.



Seventy-five meter swivel pylon of the Kuibyshev-Urals high-voltage line.





Lenin Hydroelectric Station on the Volga. High-voltage Protection system for the open-air distributor.

pleted on the Eastern branch from the Stalingrad Hydropower Station to Moscow, which will be 1,050 kilometres long and carry electricity at 500 kv. This is no limit, however. Plans are afoot to build a 650-kilometre line of 800 kv in the Soviet Union soon.

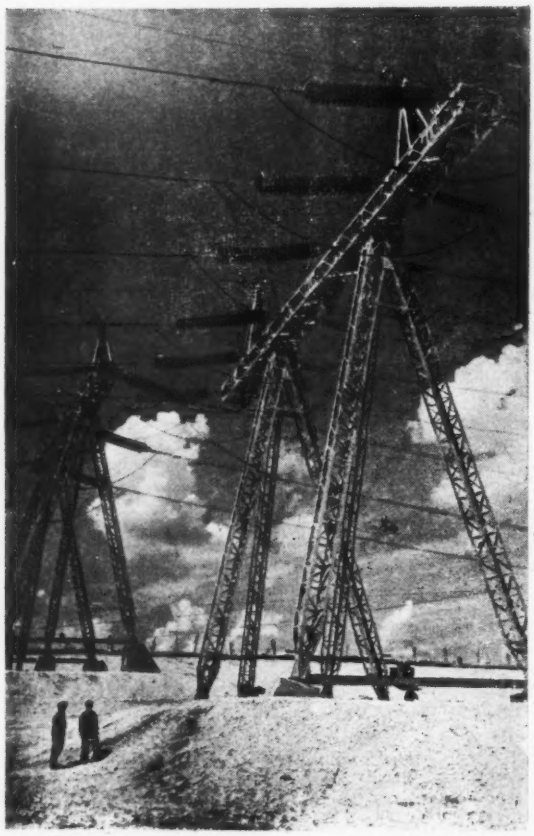
In 1958, the Soviet Union built 6,000 kilometres of power transmission lines, or as many as the United States in the same year.

This year (1959) some 14,500 kilometres of lines will be commissioned in the Soviet Union, or nearly two-and-a-half times more than last year. It shocld be added that these lines will be better equipped than American.

WORLD'S FIRST

Engineering preliminaries have been started on the Stalingrad-Donbas power transmission line in the Soviet Union. This will be an unusual line.

Pylons of the high-voltage lines: Lenin Hydro-electric Station on the Volga-Urals, and the Lenin Hydro-electric Station on the Volga-Kinel.



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Editorial

International Water Resources Development Centre

With the growing population in various countries the need to develop natural resources is becoming more and more urgent. Water resources constitute in this regard one of the most important. Since sometimes back quite a large number of underdeveloped countries in Asia and Africa are becoming politically independent and are planning development of their resources. So is Latin America. But for such underdeveloped countries the task is not easy due to the fact that they do not possess all the required trained personnel who can competently undertake the job in all its magnitude. Integrated water resources development, particularly of the multipurpose type, though of recent origin, has become a highly technical job combining several skills. Apart from this, in case of international rivers the conflict of interest arises. But the pace of development has to be kept up if the needs of the people are to be adequately met.

Considered from this angle the establishment of the Water Resources Development Centre in the United Nations Organization represents a new phase in international co-operation of great significance. Its first biennial report makes impressive reading in the sense that a great step forward has been ably taken. Its major function is "to promote co-ordinated efforts for the development of the water resources." Its individual tasks are described as follows:—

(a) to keep the interrelated problems of water resources under continuous review;
(b) to co-ordinate the systematic study, by the various organizations concerned, of problems related to water resources development in general and river basin development in particular;
(c) to strengthen and ensure good co-ordination of technical assistance activities in respect of water resources;
(d) to foster in the case of international rivers, as appropriate, the collection of relevant data, the study of tentative programme schemes and bringing together of the parties concerned; ...
(e) to promote efforts towards the formulation of principles of international law applicable to water resources development; and
(f) to foster the diffusion of relevant information among Governments and interested organizations.

It is understandable that so soon after its establishment it cannot discharge all its functions. This is particularly so, as they cannot be undertaken without the fullest co-operation of all the governments concerned. But the way in which the Centre has begun applying itself to the task of contacting the various agencies and governments related to water resources development is indeed admirable.

As our readers are already aware, it has been the vigorous policy of this journal to encourage international co-operation in the matter of development of international rivers. We therefore greatly appreciate the efforts of the Centre in this direction. This is a field which needs to be stressed in the coming years. Both for the purposes of maintenance of peace and the promotion of resource development in the future, it is important that methods of international co-operation are evolved and that an international agency exists through whose good offices such co-operation between successive states can take place. We are therefore glad that the Centre is trying to promote "efforts towards the formulation of principles of international law applicable to water resources development."

We are also glad to note that the work on the Lower Mekong Basin is shaping well under the auspices of the Committee for the Co-ordination of Investigation of the Lower Mekong Basin, composed of representatives of Cambodia, Laos, Thailand and the Republic of Viet Nam. This is a major Basin Project covering several small States and with tremendous potentialities of development. If this major effort in international co-operation succeeds, it will provide a great example of what can be done in several other areas.

As if anticipating this prospect, the Centre is following up the report on *Integrated River Basin Development* published in 1958, in preparing preliminary surveys of selected international river basins. A comprehensive report on the results of these surveys would then be communicated to the respective governments concerned. Such detached, competent and well-considered reports would, we are sure, prepare the ground for quicker international co-operation.

The Centre as well as the other agencies of the U. N. are, in several other various ways, bringing about international co-operation in the matter of water resources development which are mentioned in the Report. All these go to show that just as intensive local effort is necessary to promote resources development in backward areas, it is equally necessary to organize and co-ordinate international co-operation, both as between adjacent countries, and as between the developed and the underdeveloped countries. And for all these the existence of a world Centre would prove invaluable.

Our Contributors

Mr. V. Venugopalan took the B. A. (Hons.) degree of the Madras University in 1929 and Certificate of Proficiency in Electrical Technology from the Indian Institute of Science, Bangalore, in 1933. He joined the Madras Government Electricity Department in 1934 and worked in various capacities till 1947, when he was elected by the Government of India as Project Officer in the late Central Technical Power Board, Simla. He is now Director (Transmission) in the Central Water and Power Commission (Power Wing). He spent four months in Sweden and Norway in 1952 under the U. N. Fellowship Programme for specialised studies on the design and construction practices of extra high voltage transmission lines. In 1954, he attended the Golden Jubilee Session of the International Electrotechnical Commission in Philadelphia as one of the members of the Indian delegation. On his way back from the U.S.A., he spent about a week each in Canada, U.K., France, and Switzerland and studied the latest practices relating to high voltage transmission and distribution systems in those countries. In 1958, he attended the CIGRE Meetings in Paris as a delegate from this country. As chairman of the Electrical Conductors and Insulators Sectional Committees of the Indian Standards Institution, and convenor and member of several Subcommittees and Panels, he has been actively associated in the standardisation work both at the national and international levels. At the Commonwealth Standards Conference in 1957 in Delhi he was the chairman and leader of the Indian delegation of the Technical Committee on Cables.

Mr. L. W. Boxer A.M.I.E.E., is in the Atomic Power Division, English Electric Co. Ltd.

Mr. C. S. Parthasarathy Assistant Chief, (Irrigation) in the Planning Commission and is one of our frequent contributors. This article completes his series on Irrigation Policy.

Mr. Baleshwar Nath B.Sc., C.E. (Hons.), M.I.E., was till recently Secretary of the Central Board of Irrigation and Power and was the Organising Secretary of the Asian Regional Conference on International Society of Soil Mechanics and Foundation Engineering. He is at present Member, Irrigation and Power Team, in the Planning Commission.

Mr. J. W. Ridley M.A. (Oxon), B.E., A.M.I.C.E., M.N.Z.I.E., took Bachelor of Engineering and Bachelor of Science degrees at Canterbury New Zealand University; during the last War he served with the New Zealand Divisional Engineers in the Pacific and in Italy. In 1946 he was selected as a Rhodes Scholar and completed his M.A. at Oxford, England, with Honours in Engineering Science. He returned to New Zealand in 1948 after working briefly on hydro-electric schemes in the North of Scotland and in North America. Since that year he has been on the staff of the Ministry of Works, first on investigation for hydro-electric works, and subsequently on design. At the time of being appointed to Otematata he was acting Assistant Chief Designing Engineer (Hydro), Wellington.

The highest honour annually accorded by the New Zealand Institution of Engineers, the Fulton Gold Medal, was awarded to Mr. Ridley in 1954 for a technical paper on "Seepage and Uplift Pressures in Hydraulic Structures." Later that year he spent some time in the United States studying hydro-electric engineering, and in particular the design and construction of earth dams.

Mr. Ridley is now Project Engineer, Otematata, in local control of all the work at Benmore, on the Waitaki watershed, and at Roxburgh where the final four 80,000 kW generators are at present being installed.

Mr. D. C. Datta M.Sc., was Technical Officer in the Indian Statistical Institute and a member of the West Bengal Statistical Service. He joined as Statistical Officer in the D.V.C. and is at present Senior Research Officer in the Programme Evaluation Organisation, Planning Commission.

[*Continued from page 34*

New Developments in Soviet Power Engineering.

For it will transmit direct rather than alternating current at the world's highest tension of 800 kv. This will be twice as high as the voltage on the existing lines.

What will this new line be like? This will be a two-wire line some 473 kilomettres long, incorporating two transforming substations at Stalingrad and the Donbass.

The power will be transmitted both ways. When it is high water on the Volga, it will flow to the Donbass. At low watter electricity will be transmitted from the Donbass to Stalingrad. Besides, at night when the Stanlingrad Stattion should better work at the minimum power output (so as to accumulate more water) the adjacent area will get 250 to 300 thousand kilowatts from the Donbass. When going to the Donbass, alternatintg current will be converted into direct to be re-converted into alternating at the Mikhailovskaya Substation in the Donbass.

The service buildings of the line will house control boards, switchgears, instruments and protection relays. A system of automatic controllers will ensure troublefree operattion of the line.

The wires will be arranged on metal masts 22.5 metres high and spaced at 340 to 370 metres. The masts on the banks of the Don River will be still higher. The wires will be suspended on chain insulators each 4.4 metres long.

Up to 4,000 million kw-hrs of electricity will be transmitted over the line both ways daily.

The aggregate power-handling capacity of the line will be 750,000 kw, though, if necessary, it can be raised to 900,000 kw. This will be the world's first commercial line of such capacity.

Overhead d.c. transmission lines are more economical than a.c. lines. Power losses on them are nearly 25 per cent less, while instead of three they will have two wires, which feature gives substantial savings in non-ferrous metals and insulators.

MASTS FOR H. T. TRANSMISSION LINES

The staff of the Kharkov branch of the All-Union Power Engineering Design Institute has worked out a new code for masts used in power transmission lines of 110 and 154 kv.

At present, about 80 types of mast, made up of more than 300 types of metal sections, are used in the Soviet Union to suit the various climatic conditions, geographical features and wire weight. The new code envisages six times less types of masts, while the number of sub-assembly types will be reduced nearly ten times.

This code will enable the manufacturers to organize the production of masts on an assembly-line basis and to turn out twice as many masts on the same floor space.

As a result, some 15 hundred tons of metal sections will be saved on every thousand kilometres of power transmission lines.

Engineers' Circle NEWSLETTER

The Engineers' Circle functions with the object of providing to engineering, scientific and allied professions a forum for exchange of ideas—to read papers, to organise symposia and lectures, to provide facilities for cultural and recreational activities, to arrange works visits. It is proposed to publish a newsletter covering briefly the activities of the circle, as a supplement to this journal. This month's newsletter carries summaries of talks given on April 22, May 6 and May 20, 1960.

MECHANISATION OF MINES

N. P. Roy Choudhury

I HAVE dealt here mainly with the coal mines. Although coal industry itself happens to be the main source of power in India, it is at the same time one of the largest consumers of power. And this power consumption is ever increasing and vital to the industry. The miner is today relieved by the machine from the arduous, dull and dangerous work which in the past was done by manual labour. At the beginning of this century the coalmining was performed by the miner laying on his side all day and using a hand pick. Today with the introduction of electricity or compressed air, power operated drills and machines of about 50 H.P. have almost replaced hand labour in the coal face. Modern tendency is to reduce the manpower everywhere, wherever possible, by substituting machinery for men.

Where power is generated at the colliery site, generally 6% of the output is required for the colliery consupmtion, In the mechanised mines of Europe, power consumption is on average 7½ H.P./1 ton of coal/day, for winding, haulage, ventilation, coal cutting, pumping and many other miscellaneous operations.

For a long time there was little progress in mechanisation of mines mainly because of the question of safety. Since electricity is the source of ignition, it was not much popular until recently when safe electrical apparatus was designed for the gassy mines. The use of electricity is always attended by two possible dangers, namely, those of shock and fire. The first one is eliminated by the proper earthing, where fire is eliminated by the use of the equipment of suitable design and adequate size. The safe use of electricity is achieved by (i) intrinsic safety method for low power units, e.g. bells, relays, batteries, telephone, shortfiring and pilot circuits, and (ii) flame-proof apparatus for power plants, motors, switchgears, controllers and the like. By intrinsic safety method the intensity of the sparks is reduced or damped, to make them so weak that they are incapable, in normal working, of igniting even the most easily ignited mixture of fire damp and air. A flame-proof enclosure for electrical apparatus is one that will withstand without injury any explosion of the prescribed inflammable gas (fire damp in mines) that may occur within it under practical conditions of opertaion within the rating of the apparatus, and will prevent the transmission of flame such as will ignite the prescribed inflammable gas which may be present in the surrounding atmosphere. The necessary requirements for this type enclosure are that it should have the minimum mechanical strength of 50 p.s.i. above atmospheric pressure, and the admissible gap between the flanges and the width of flange should be 0.02 inch and 1 inch respectively.

If the presence of gas is more than 1¼% electricity is not allowed there. Before flameproof enclosures and intrinsic safe apparatus came in, compressed-air driven machinery were used in the gassy mines. But it was a very costly affair, since cost of compressed-air energy is nearly 7 to 8 times that of electrical energy.

How the use of electricity is increasing rapidly can be seen from the U.K. statistical figures. Within 36 years, from 1912 to 1948, the power consumption became 7 times, and the number of person killed in accidents fell appreciably. Accidents occur mostly due to the human factor now-a-days. With proper precautions in the choice, maintenance and operation of the machinery, the danger of explosion can almost be eliminated.

Adequate ventilation is of vital necessity in the prevention of mine explosions. The main purposes of it are (i) to provide air for breathing of men, (ii) to replace impure air by fresh air, (iii) to cool the working places, (iv) to carry away dust. The magnitude of the problem, as seen by the mining engineer, is not realised by many non-mining persons. In the United Kingdom for every ton of coal mined it is necessary to circulate through the mine anything from 3 to 12 tons of fresh air, depending upon the gassiness of the seams worked and the depth of workings. Ventilation was achieved previously by he crude method of making fire at the pit-bottom of the upcast shaft, this making a natural drift. At present the fan capacity goes up to 29,000 tons/

day with a horse power of 2500 or more. These fans are of either axial-flow or centrifugal type.

Pumping consumes also a lot of power in some of the collieries. The consumption varies according to the local conditions. Some mines are comparatively dry. In some mines it may go to 20 times or more than the tonnage of coal mined. Primary source of water in underground is rainfall, one third of which sinks into the ground. According to the nature of rocks and the various levels of depths, the amount of water varies at the working site. Now-a-days mostly centrifugal pumps are used. Monopumps are used for local areas. In the Jharia coalfield approximately 50% of the total power consumed in the collieries is needed for pumping.

Transport originally constituted of men carrying sacks on their back, or the ponies. Then tubs were introduced and pushed by men or pulled by ponies. Now-a-days haulages, chain conveyors, belt conveyors, steel-plate conveyors, electric locomotives and the like are used.

Some of the latest type of underground machinery at coalface are coal-cutters, cutter-loaders, combines, coal ploughs, shuttle cars, loaders and self-walking steel props. The goaf is caved or stowed either hydraulically or penumatically. With the help of a coal plough and a panzer conveyor the face length of a longwall system can be extended up to 1000 m within a production of 1000 tons /day even. The raisings of some mechanised collieries in Europe are on average 7000 tons to 9000 tons/day. In Germany last year complete mechanisation was celebrated in Friedrick Heinrich Colliery, and there no longer men are needed at the coalface.

In India the seam thickness varies from 6 to 110 ft. and most of the seams are flat. So, it is easier to work here manually right up to the coalface. Roof support is little needed here owing to the shallow depths and standtone roofs. Because of the greater seam thickness and strong roof condition bord and pillar method is used here to win the coal—instead of longwall system as used in the thin seams of Europe. But this great thickness of seam is not an advantage, for only 60 to 70% of coal can be extracted during depillaring. Prior to independence majority of the collieries were in private hands. Without proper care and safety methods they used to get coal, mostly of valuable metallurgical type, leaving the rest 40% of coal in the goaf with a single view to making a huge profit. After independence, the Indian Government laid down some restrictions in regard to the winning of metallurgical coal and has been helping the mine owners with stowing materials so that a major portion of coal can be extracted. In the bord and pillar method however, even by stowing full extraction is not possible. Therefore there is now a strong opinion in favour of introducing the longwall method of working in several steps, either with caving or stowing.

Mechanisation can yield positive results only when the miners are properly trained, skilled and careful about their duties. They should not only know how to handle machinery, but also must have the spirit of team-work and some knowledge of mining and safety methods. The Government of India is doing a lot in the direction by opening training centres in the coalfields.

JOB EVALUATION

K. Venkatachary

IT is well known that to get the maximum out of people working in any organisation, they should be kept satisfied. Two major factors which govern this are (i) establishment of a fair day's work and (ii) payment of a fair day's pay for a fair day's work. This first factor is dealt with by work study to an acceptable accuracy. It is the second factor that offers considerable difficulty in the way of satisfactory settlement. From time immemorial the question is asked: why and how there are disparities in salaries or wages. People have vague ideas about value of their own jobs in relation to others and they are pained to find that others are better paid for what they term as 'easier' and 'less' important jobs. Disputes may also occur in payment against new jobs regarding the level they would occupy in relation to the existing jobs. All these point to the need for an objective way of determining the intrinsic value of each job as measured by a common yardstick, for properly fixing the levels of all jobs within the same unit. This is where job evaluation steps in.

Job evaluation seeks to analyse, assess and evaluate the relative worth of contemporary jobs to enable establishment of an objective wage structure. It should be noted that job evaluation is by no means a perfect or even fully objective approach to the settlement of the relative merit of a job. Judgement forms an unavoidable major factor in this approach and it can only be claimed that out of several attempts made in this endeavour, job evaluation has been found to be comparatively most objective, offering satisfactory settlement in wage disputes.

Three major steps in job evaluation are : (i) job specification (ii) job assessment and (iii) job evaluation proper. The first step, viz, 'job specification' requires a practicably accurate picture of the job as to its requirements by way of skill, physical and mental capacities, responsibilities, working conditions, etc. Special questions are usually prepared and got filled up by either the person doing the job or the person to whom he is responsible to or both, to avoid probable individual bias. The filling up is done preferably under the direction of the person who prepared the questionnaire. The questionnaire is to be prepared discretely to elicit all the information required under classified headings like skill, physical requirements, responsibilities, etc.

Vague answers are to be avoided as they are as good as no answers and likely to lead to erroneous evaluations.

The second step, viz, job assessment is a matter of opinion. This is preferably left to a committee as the assessment of a group has lesser bias and greater accuracy than that of individuals. The relative importance of each factor in the job is assessed and expressed as a percentage of the whole.

The third step, viz, job evaluation proper is mostly mathematical in its approach. Two systems are followed in this case: factor comparison system and weighted points system.

In the factor comparison system, the existing jobs in the whole organisation are scrutinised with respect to the corresponding rates of payment and a few key jobs which are represenative, clearly desirable and, in the judgement of the scrutiniser, fairly paid, are selected. From the data provided by the questionnaire, these jobs are ranked according to their relative value, for each major factor. The money value of each of those factors in the job is then culculated based on the assessments of the relative importance of the jobs expressed as percentages of job and on the corresponding payments. Depending upon the rank of each factor for each job and the corresponding money value, trend graphs are drawn. Readymade charts are prepared from these and in the case of the rest of the job, the factors are properly located in the chart and the corresponding money values arrived at. The total money value of all the individual factors will give the rate of payment for the job under evaluation.

Selected key jobs which do not conform to the trend graphs are reviewed and eliminated if found to be unrepresentative.

This system is simple but too general in approach and involves considerable subjectivity. Weighted points system is an improvement on this in that the factors are themselves further divided into sub-factors. The relative value of each sub-factor is determined by trend graphs just as in the other system. But each sub-factor is evaluated in points instead of in cash and the cash conversion is done in a second distinct step. The number of points for the scheme depends upon the organisation. The more the points, the more will be the accuracy, but more also will be the complication in evaluation. Certain minimum points are usually allowed for the basic requirement for the presence of a person for the job, known as "basic human requirement." A final chart giving payment against job evaluation points is prepared as in factor comparison system on the basis of selected key jobs, screening non-confirming points by trial and error. To avoid a diffrent rate of payment for each job evaluation point, the wage curve is divided into grades.

A successful job evaluation scheme requires an impersonal evaluation of the job. That is evaluation should be of the job and not of the person. The scheme should further be made to suit individual organisations; for a scheme successful in one organisation may well be a failure in another where different conditions may be obtaining. It is also desirable to introduce the scheme in an entire organisation rather then in sections. Since the object of the scheme is not only making a fair evaluation of the jobs but also ensuring that the employees are cognisant of the fairness, no screening should be maintained as to the system of evaluation. There should also be proper channels of appeal for settlement of wage disputes. A satisfactory and practical scheme is worth much more than a theoretically perfect one.

FINANCIAL INCENTIVES

A. Khuller

BEFORE discussing how financial incentives may work in industry, the need for incentives—monetary or otherwise—and the goal they are directed to may be briefly considered.

Whether any work is mental or physical or, as is generally the case, a combination of the two, for an individual to alter his behaviour pattern (work being essentially that) there must be the will and the inclinaion to do so. Though the behaviour pattern can be changed by using deterrents, the "co-operation" achieved in this way is under a stress of compulsion—motivated through fear and not likely to last long. On the other hand the will to co-operate issues from self-interest aroused by suitable incentives—psysiological, psychological, social, economic and the like, depending upon the individual concerned.

In the present situation of the individual being more concious of his basic rights and requirements, the incentives have to be in the light of the objectives which the community upholds. They include improved standard of living, prospects for the future, equity between earnings and effort, degree of satisfaction with the nature of work and the level of earnings.

Individuals differ, and hence it is sometimes contended that whereas for one a "fat" pay packet may work as incentive, for another just a word of appreciation may suffice. But the latter perhaps is a more or less economically satisfied person. The monetary incentive has for him lost its pull at a certain time in relation to other motivations; not that money was never an incentive to him. It would be proper to assume that the power of any incentive varies not only from individual to individual but also varies according to situations.

Money essentially represents the power of purchase, vested in the possessor; the power is exercised by the individual to satisfy his wants and desires. Thus financial incentives are very important in our civilisation.

There are various systems of financial incentives in industry. The incentive payment under which the worker's earnings are related directly to some measurement of work done either by himself or by

the group to which he belongs. All these can be classified in four main groups according to the relation of earnings to output namely, (i) in the same proportion as the output, (ii) proportionally less than output, (iii) proportionally more than output, and (iv) in proportion which differs at different levels of output.

The same proportion.—In this classification the worker's reward varies in the same proportion as his output, that is to say, any gains or losses resulting directly from changes in his output accrue to him (leaving any gains or losses in overhead cost per unit to the employer). In contrast on normal daywork, any gains or losses accrue to the employer. The successful operation of this type of system requires extremely accurate measurement of standards by proper application of work study.

The straight "piece work" is the most common under this system; frequently this is somewhat modified by guaranteeing a minimum wage, designed to protect the worker against unduly low earnings due to factors beyond his sphere of control. In this type the worker is paid a specific rate per unit of output; the unit may be weight, length and numerical quantity. Direct labour cost remains the same above the standard output.

The standard time system is essentially the same as the straight "piece work" system and is becoming increasingly popular. It has the additional advantage that changes in the basic wages do not alter the standard time while it could result in changing the piece work price of all jobs, if straight "piece work" is in use. The basic measuring tool being time, inter-departmental or inter-firm comparisons are possible.

Less proportion—In this type the worker shares with management the gains or losses resulting from changes of output. This type of system is often applied where it is not possible, economically or otherwise, to set standards accurately or to measure workers' output accurately. Under this system the worker receives progressively less for increases in output. In most cases there is a minimum guaranteed wage. For significant increases in the production the profits are higher.

A few of the widely applied schemes under this class of incentive payment are noted below :—

1. 50/50 Halsey System. In this case 50 per cent of the time saved is given to the worker as bonus.

2. Rowan System. In this system, if 'x' be the percentage of the time saved to the standard time, the time taken to do the job plus x per cent of the earnings are for the time taken.

3. Barth System. In this system the total earnings of the worker are given by the relation $\sqrt{\text{time taken x standard time x hourly rate}}$.

In all these systems it is impossible for the worker to go above a predetermined "top limit" of earnings or, in other words, a "ceiling" is put on to bonus earnings. This "ceiling" or "top limit" has a tendency to act as a disincentive, besides the fact that the workers themselves "adjust" their output to give them a fixed bonus earnings, rather than work their best and run the risk of having the rates cut because of too high a bonus earning, indicating "loose" standards.

Greater proportion.—In this type the worker not only gets the gains by virtue of his increased output but also shares with the employer the gains achieved by reduced overhead cost per unit. The payment curve may either be a straight line or some form of mathematical curve, giving varying levels of earnings at different levels of output. The systems are not, however, widely in practice; they are quite complicated, and the primary requisite of a good incentive, that is that it should be easily understood and taken by the worker himself is missing. Any system by which the worker is unable to arrive at his bonus earnings from day to day, and is therefore unable to check his earnings, is likely to be viewed with suspicion. These systems are usually favoured by industries in a monopolistic condition or if the product has an abundant and ready market where the best worker is attracted by extra high earnings, to get a maximum of labour productivity. It is common, however, in these systems to set the standard or target fairly high so that the relation of earnings to effort is not much different to other forms of incentive payment. It is quite essential is these systems to be very correct in the setting up of standards.

Accuracy and equity being desirable, the simplest and the best systems to operate upon are those based on work study, though work study is not easy to introduce. These systems are more easily accepted by labour now-a-days; bargaining and negotiating for each standard have been reduced considerably with a work-study base.

High labour productivity in itself is difficult of achievement and maintenance unless other functions of management viz: planning, costing etc. can keep pace with it. Work study is ideally suited as a tool of management to maximise the advantages of a good incentive scheme. Best methods are established, standard times being measured in the most accurate manner practicable and excess or lost time is recognisable easily and hence remedied. In most firms such lost time is "hidden".

Deciding on the most appropriate scheme for a particular situation and having collected the data, the next and the most important step is the implementation of the scheme. Here a joint labour-management consultation is essential and at this stage it is up to both the parties to incorporate clauses in the agreements safeguarding their respective interests. The labour would be interested to provide against rate cutting, redundancy, minimum wage guarantee, and the like whereas the management would want to include a proviso for a change in the standard time or rate if the methods, material, machine etc be changed. But no incentive scheme is worth the paper on which it is prepared unless the labour agrees to adopt it or at least try it. The management must therefore try to meet as many of the workers' doubts as possible, while safeguarding against quality, excessive earnings, etc. The important point is that the scheme must be fair and both parties must co-operate fully.

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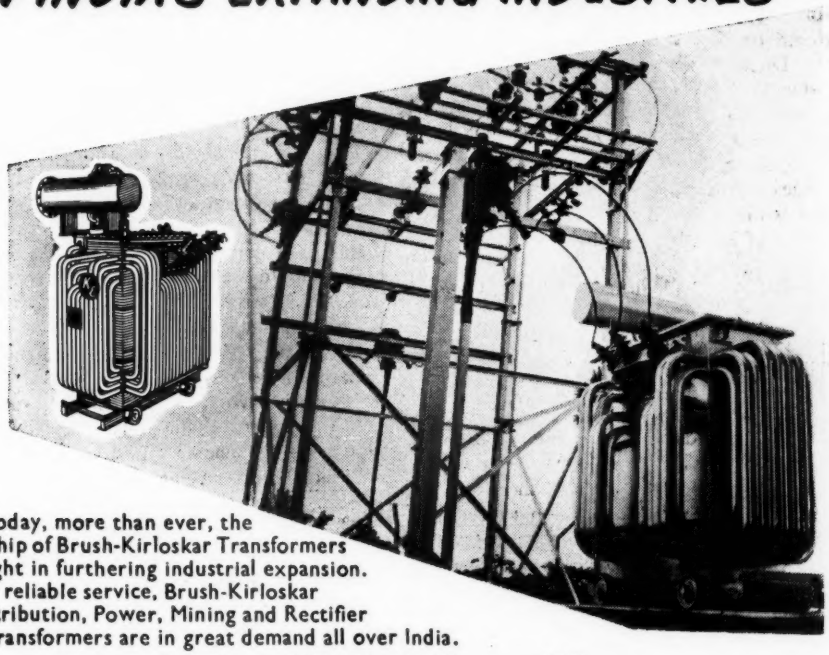

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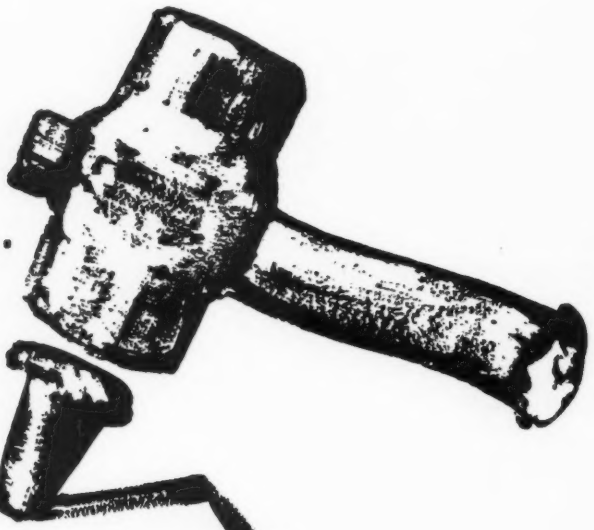

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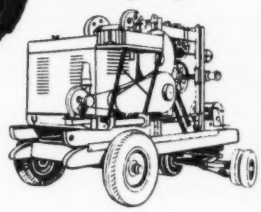

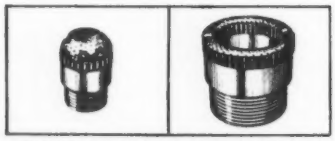

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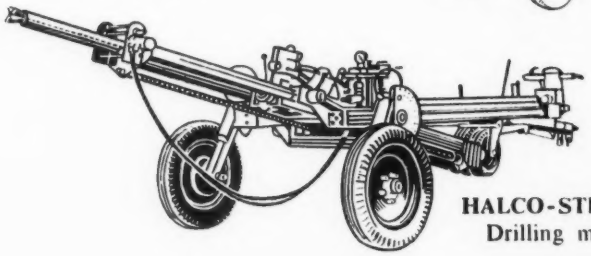

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